MATERIALS OF CONSTRUCTION ISSUE

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CHEMICAL & METALLURGICAL ENGINEERING

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g. Concrete for Chemical Tank Construction
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Special Editorial Supplement to This Issue

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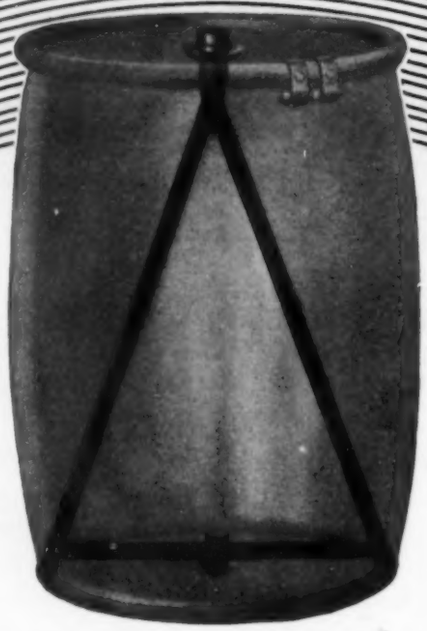

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S. D. KIRKPATRICK, *Editor*

MATÉRIEL

for a

Chemical Engineering Army

ARMY ADVANCES depend upon matériel as well as personnel. A break in the service of supplies—too great a gap between men and munitions—means slow progress, if not ultimate defeat. A few years ago such a situation existed in chemical engineering. Process personnel had pushed far ahead while matériel in the form of construction materials and available equipment had lagged sadly behind. Lately, as a result of remarkable improvements in materials, the gap is rapidly being lessened. This fact is already reflected in better processes and more profitable production in chemical engineering industries.

TO RECORD the many developments that have placed these improved materials and more efficient tools in the hands of the chemical engineer is the underlying purpose of this issue of *Chem. & Met.*—the fourth of a series to deal exclusively with materials of construction for chemical engineering operations. When the first of this series was published, in April, 1923, it was with the promise that the problem of materials would be reviewed at appropriate intervals. That earnest was responsible for the Corrosion issue of July, 1924, and the Severe Service number of October, 1926. Each of these recounted material progress, but none, perhaps, on the comprehensive scale of the present survey. Here the best of industrial practice in the use of metals and alloys, brick and cement, wood and stoneware, glass and enamel, rubber and plastics is discussed by maker and user, but always with the requirements of the chemical engineer in mind.

NOT ALL of the demands of the chemical engineer are easily met. For instance, there is an insistent request for specific data on corrosion and other equally practical properties of metals. The manufacturer, although willing to co-operate to the utmost, has sometimes found it difficult to reduce these facts to the statistical form of most convenient use. Progress is being made too rapidly: the best alloy of today may be obsolete tomorrow. Nor is the subject of corrosion one that lends itself to quantitative treatment—particularly in the hands of those who fail to recognize the many limitations of laboratory tests. Yet in the face of this difficult situation, the help of several hundred manufacturers has made it possible for *Chem. & Met.* to compile the comprehensive series of data sheets which are presented as a special supplement of this issue. They are commended to the reader for careful study and practical use.

AS A WHOLE this issue cites much encouraging progress in matériel as well as the definite assurance of continued improvement. The personnel of the chemical engineering army is now equipped to push forward to the successful conquest of more corrosive substances, difficult processes and obstructive conditions. Adequate matériel is available for history-making advances.

What the CHEMICAL ENGINEER Demands of CONSTRUCTION MATERIALS

By W. R. Huey
Engineering Department, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

THE IRON MASTER of the nineteenth century, peering into the blinding glare of his crucible, could not hope to see the reaction vessels of 1929 half hidden in the shadows beyond. The chemist, a few years later, had visioned the possibilities of new products in great abundance that were to be born of great heat and pressure or low temperature and lack of pressure. Today the descendants of the iron master and the chemist, who have become better known as metallurgical and chemical engineers, have formed a closer alliance than then existed. They are working in more intimate knowledge of their mutual problems and the wonders of modern science are being wrought thereby.

TODAY the chemical engineer is living the dreams of his predecessor because his metallurgical colleague is meeting in noble fashion his demands for stronger and more enduring materials. Corrosive raw materials are brought together under pressures of thousands of pounds per square inch at temperatures approaching a thousand degrees Fahrenheit in order to produce compounds that tax the containers and pipe lines to the utmost, even under normal conditions. Working with the metallurgical engineer, these two disciples of the modern school of science are revolutionizing great industries and cutting cleanly through the threads with which monopolies tethered certain phases of industrial development not many years ago. What sweeping changes in the economic pattern of the world will be wrought in the years following tomorrow?

Before it was possible for the chemical engineer to achieve his radical scrapping of old methods during the World War, new materials of construction and new technique for using them had to be developed. The burlap nitrate bag had to be replaced by sturdy tanks of steel, the pots and pans and picks of the nitrate fields had to be transformed into reaction chambers of more noble stature. Low-alloy steels of nickel, chromium and vanadium turned the trick and heat treatment was the magic wand waved by the metallurgist's hand. The cast-iron pot with its glass and stoneware accessories went to the scrap heap to make way for the gleaming towers and tanks of high-chrome stainless alloys that arose on the old foundations. Ammonia synthesis and oxidation had sent nitric acid flowing into the old channels of the chemical industry with new vigor and at lower cost.

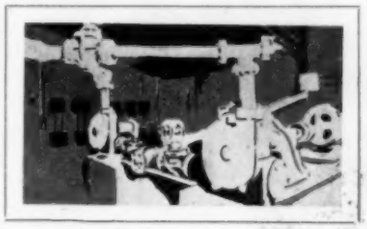
The comparatively recent commercial development of iron-chromium-nickel alloys on a large scale is probably the metallurgical news of the day. Through the medium of publicity of both the direct and subtle sort, even the man in the street has learned to know the stainless steel and iron alloys as more than the novelty they were a few years ago. But perhaps it is not so well realized that *there are over three thousand other alloys of the ferrous and non-ferrous type.* The metallurgist has been prolific during the years since the iron master mixed his batches for horseshoes and garden gates. As the chemical engineer contemplates the long list of alloys, he is likely to become confused in making the choices that will mean so much to the success of his process and to the earnings of his company. His state of mind is not improved if he has lent an ear to the extravagant claims of some few of the peddlers of alloy wares.

No doubt a large proportion of the hundreds of alloys serve many useful purposes, but very few of them have real value in a plant manufacturing corrosive compounds. The metallic corrosion-resistant materials of practical economic value in the severe-service field may be counted as an even dozen or two. They are aluminum, chromium, copper, iron, lead, nickel, silicon, silver, tin, zinc and their combinations. To the latter term should not be assigned the mathematical interpretation in this instance, for there are relatively few combinations that are of any value for corrosion resistance.

In addition to the metallic materials for equipment construction there are also hundreds of non-metallic compounds, which, in the main, have very limited use. The few that are of value to the chemical engineer are fused silica, glass, rubber, stoneware, wood, condensation products of phenols, or resinoids, and certain paints and plastics. With the exception of fused silica, glass, rubber and stoneware these materials have relatively small use as resistors to severe corrosion.

WITH the long list of alloys and non-metals restricted to a small number of practical applications for the engineer in the chemical industries, it may be classified on the basis of degree of applicability. Assuming for the moment that resistance to acid corrosion is the only requirement, there are the materials of an *extensive* application and those of *limited* application. For some purposes a few of the materials can justifiably be placed in either class, but in general there are only four materials being used in the chemical industry today that may be correctly considered as having very extensive application. They are high-silicon iron, fused silica, glass and stoneware. All others have only limited applications, which are in some instances extremely restricted. The stainless alloys may be used in nitric acid of reasonable purity under all conditions of temperature and concentration. In this particular instance, therefore, these alloys fall within the *extensive* classification and it is the nearest approach made by any of the limited materials.

On the basis of corrosion-resistance, the above-mentional materials have well-nigh universal application. In respect to mechanical properties, however, high-silicon iron, fused silica, glass and stoneware share to some degree the common faults of brittleness, great hardness, and breakage caused by temperature change. Thus they may be considered the Dr. Jekyll and Mr. Hyde of the corrosion-resistant materials. The stainless alloys for the most part have high strength, durability and excellent resistance to temperature change as well as to damage at high temperatures. Of the materials of limited application some are limited by undesirable mechanical properties as well as by inferior corrosion resistance, while others have superior mechanical properties but limited corrosion resistance.



Unfortunately, in most cases of chemical equipment construction consideration must be given to factors other than corrosion resistance. Mechanical strength and malleability are usually requisite qualities, and usually first cost is an important factor. Therefore, possible use of the extensively applied materials must yield to the more limited and more practical use of such materials as cast iron, copper, lead, and steel. For the most effective use of the limited materials a thorough knowledge of their faults and qualities is essential. Supported by this knowledge, sound judgment then determines what may be safely sacrificed in order that certain gains may result. In the order of tonnage use in the chemical industries, lead, iron, copper and nickel head the list of the metallic corrosion combatants.

Lead is used chiefly as sheet and in the pure state, with the exception of the hard-lead alloys required for valves and pumps. During recent years rapid progress has been made in applying lead lining to pipes, fittings and valves. Although lead enters the limited classification group partly because of low resistance to several corrosives, probably a greater limitation is lack of strength and hardness, and low melting point. Because of low strength it is often necessary to devise rather elaborate supporting systems. Resistance to erosion is quite low due to softness, but resistance is high to impact of certain types or friction such as encountered in bearing service. At temperatures in excess of 250 deg. F., corrosion resistance decreases sharply and mechanical weakness, exhibited by "creeping," becomes more pronounced.

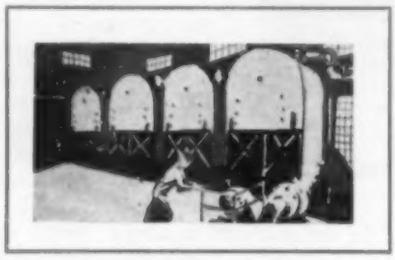
With many metals of 99 plus per cent purity, the "plus" contains impurities in small amount that exert a disproportionate influence on the corrosion resistance. By the intelligent control of these "plus" ingredients of relatively pure lead, the service life of equipment can undoubtedly be increased materially. Several investigators have studied the effect on the corrosion resistance of such impurities as copper, arsenic and bismuth, and some interesting findings have been made. The exceptional corrosion resistance of sheet lead in sulphuric acid chambers which have been in service several years is ample testimony that between 99 and 100 per cent is a material possessing real commercial value in reducing maintenance costs.

Of the iron-carbon alloys (steel) and the low silicon-manganese-phosporus-sulphur iron alloys (cast iron), the latter probably have the most wide-spread use in the chemical industries. Contrary to prevalent opinion, cast iron is in reality a class name for a group of low alloys of iron. When this conception is more fully understood, the scope of effective use of cast-iron alloys in corrosion-resistant equipment will be broadened considerably. Cast iron is included in the limited classification more on account of low corrosion resistance than because of the inferior mechanical properties that limit the use of lead. Frequently the relatively low cost of cast iron and the decidedly attractive mechanical properties which may be obtained by heat treatment of certain grades, make it worth considering in spite of quite low chemical resistance. For instance, by the addition of about one per cent of manganese or by increasing the ratio of combined to graphitic carbon, excellent resistance to abrasion and erosion may be obtained. By modification of chemical composition and by means of heat treatment the corrosion resistance as well as mechanical properties may be enhanced.

It is well known that there are cases of exceptional service recorded for cast-iron water pipes and wrought-iron structures, the most notable of the latter being the Delhi pillar. It is also common experience in chemical plant operation to note wide variation in the life of equipment under more corrosive conditions than those of soil and atmosphere. Such variation in the service performance of cast iron may be due to differences in composition and heat treatment or to physically-defective castings. The ultimate corrosion failure of cast iron is often marked by the appearance of cavities. Seldom is the corrosion of the more uniform type that is frequently characteristic of metals which have been rolled or forged.

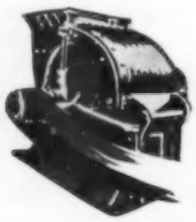
There is a tendency for cast iron to exhibit foundry defects such as shrinkage cavities, blow holes and gas pockets. The presence of these defects

in a casting decreases the service life arithmetically by simple subtraction from the original wall section. The spotty type of corrosion failure caused by composition is generally hastened in a geometrical fashion, because of galvanic influences arising from difference in electrode potential, promoted by the



presence of segregated constituents. A thorough study of the effect of small variations in the ingredients of cast iron and of the heat treatment on the corrosion resistance is indeed a fertile field of research.

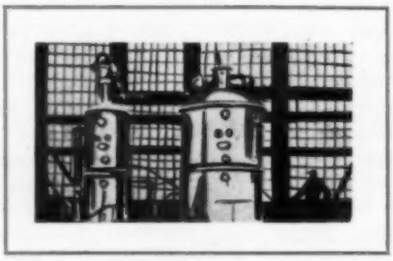
Copper has been used by both savage and civilized man for centuries. Stronger than lead, more ductile than cast iron and in general more resistant than both, this interesting metal has wide-spread use in many chemical processes. The content of impurities is very slight and they have practically no effect in commercial copper on corrosion resistance. Probably the most significant feature in the use of copper for chemical equipment is the serious and rapid corrosion damage caused by galvanic action through physical contact with other metals. Copper-base alloys of the bronze type



are extensively used for resisting certain chemicals.

The peculiarities of the half dozen or more metals most widely used for the chemical plant might be discussed in great detail. What has been said of the outstanding items of this type, is illustrative, however, of the knowledge that is necessary for the most efficient use of the limited class of corrosion-resisting metals. Nickel and Monel metal, the most important nickel-base alloy for corrosion resistance, are both used extensively in the manufacture and handling of chemicals. The chief claim to importance of silicon is as an alloying element. The high cost of silver limits the use to relatively small proportions but a few important purposes are served. Tin and zinc are used at present chiefly as protective coatings on iron.

With regard to the extensively applied materials, the almost universal corrosion resistance has prompted the exercise of active ingenuity and industry in partially overcoming some of the mechanical objections to more wide-spread use. The outstanding development of boro-silicate industrial glassware and the commercial application of glass enamel to steel as a lining have contributed materially to the value of these members of the group. A steady improvement in stoneware has been noted and many tanks in the chemical plants are lined with stoneware brick and connected together with stoneware lines. Natural aging of the high-silicon iron alloys seems to reduce the objectionable brittleness. Perhaps it is not expecting too much to foresee still further improvement in



mechanical properties of these alloys through the medium of artificial aging.

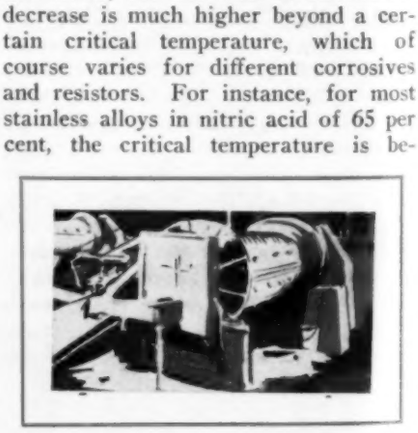
PREPARED with a thorough knowledge of the construction materials available, the designer is ready to approach the study of process conditions that ultimately decides the final choice. Great care in determining in detail the conditions of the ingredients, the reaction and the products of a process will yield a handsome return in added months or years of equipment life. Wherever possible, plant tests of materials that show most promise should be made, by subjecting several samples to the various process stages. Further insurance against the oversight of some damaging minor detail may be obtained by actual operation, for several weeks, of small-scale plant equipment. If a large investment in plant is to be made the added insurance is well worth while.

The laboratory test may some day be developed to a high degree of veracity in predicting the ultimate value of resistant materials, but at best it is now a treacherous weapon. Probably in no other test procedure is "a little knowledge" such "a dangerous thing" as in the laboratory corrosion test for predicting the life of chemical plant equipment. It is virtually impossible faithfully to reproduce plant process conditions in the laboratory flask or beaker. Compensating errors may yield results with sufficient net accuracy to afford a reliable guide to proper choice of material. Or, again, the material finally chosen after laboratory tests may be immune to the chemical conditions to such a high degree that successful application is bound to follow. Otherwise, the laboratory test should be used chiefly for research work rather than as a means of determining the service value of materials.

Many brilliant brains are at work attempting to define corrosion by isolating and studying the complex influences that contribute to the damage wrought thereby. Of the many influences that determine the service life of chemical plant equipment the best known are: concentration, temperature, velocity and impurity content of the corroding agents, galvanic effects produced by contact of dissimilar metallic materials and surface conditions of the equipment in contact with corroding agents. A thorough knowledge of the effect of these influences on maintenance cost is of equal importance with knowledge of the construction materials.

Concentration and temperature of corroding agents generally have opposing effect on the corrosion resistance. Usually greater corrosion resistance is required for low concentration and high temperature. This generalization is not applicable to the concentration effect of chemical compounds which exhibit a tendency to form complex molecular combinations, with water for instance. Sulphuric acid forms at least one such hydrate and the resistance of materials in this acid varies in exception, the lowest resistance being in a short concentration range in the higher-strength zone.

Almost invariably corrosion resistance decreases with increase in temperature. This relation, however, is not direct, for the rate of resistance-decrease is much higher beyond a certain critical temperature, which of course varies for different corrosives and resistors. For instance, for most stainless alloys in nitric acid of 65 per cent, the critical temperature is be-

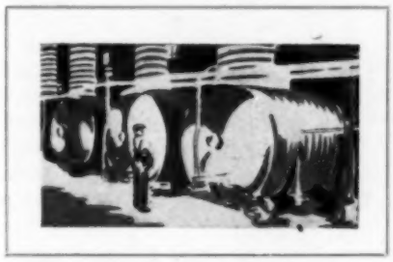


tween 160 deg. F. and the boiling point, 256 deg. F. Likewise for aluminum in acetic acid the resistance decreases very rapidly when the temperature exceeds 150 deg. F. A few degrees difference in temperature in many cases permits the use of a less costly and more desirable material of construction.

The impurity content of the corrod-

ing medium is equally as important as it is in cast iron or lead. A mere trace of impurity in an acid or salt may often prohibit the use of a metal that would be relatively immune to attack were it absent. On the other hand, traces of impurities may be responsible for a retarding or inhibiting effect on the corrosion rate. Arsenic in sulphuric acid decreases the corrosion of cast iron. A small amount of sulphates in acidified mine water may cause wide variation in service life of pumps. Hydrochloric and hydrofluoric acids as impurities in nitric acid, separately or together, cause rapid corrosion of stainless iron, which is practically immune in relatively pure nitric at all concentrations and temperatures. The presence of impurities is often not known, and seldom is the amount accurately known. Variation of impurities is quite common in chemical processes. It is futile, therefore, to attempt to duplicate this difficult phase of plant conditions in laboratory corrosion tests.

Oxygen contained in corrosive fluids may be considered an impurity and it usually varies widely at different points in the body of the fluid as well as from time to time at a given point. The



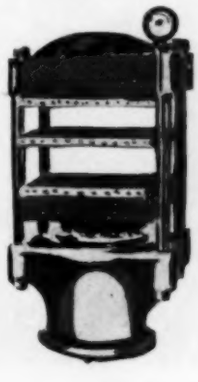
masterful research of U. R. Evans in England has demonstrated that thorough consideration must be given to this important influence on corrosion in planning the installation of equipment to handle even mild corrosives. The effects of dissolved oxygen or contact of air at liquid surface-metal junction may be seen in any chemical plant and the corrosion accelerated by this influence is sometimes serious. Chemical equipment design and operation may be modified to reduce corrosion caused by dissolved oxygen. Unfortunately neither laboratory corrosion tests nor perhaps even plant tests can accurately gage the effect of this factor.

The velocity of fluids passing through pipe lines and valves or being agitated in vessels may on occasion be controlled to prolong the service life of the equipment. Among the effects of velocity on corrosion are the removal of protective salt deposits by high velocity, the promotion of corrosion by the erosive action of high velocity, and fostering the formation of destructive salt patches under low velocity conditions. Velocity conditions are also difficult to duplicate either in laboratory or small-scale plant corrosion tests, although in the latter case the problem is more readily solved.

While the accelerated corrosion promoted by difference in electrode potential or galvanic effect is not a process condition, certain types of corroding liquids exaggerate the effect. Many cases of rapid equipment failure may be caused by galvanic corrosion, and unfortunately this type of corrosion appears where least expected. Whenever possible, the use of different metals or alloys in contact should be avoided. Galvanic corrosion may also develop from suspended metallic particles in the corroding liquid; or from the presence of scale patches on metal either when installed or subsequently formed as a corrosion product. It is therefore sometimes advisable to remove all mill scale from metals and to clean periodically the equipment surfaces that show an accumulation of corrosion products that appear to be harmful.

Galvanic corrosion may develop in metals or alloys of heterogeneous structure containing dirt particles or inclusions introduced into the metal by careless melting or rolling practice. Heterogeneity may be reduced in some instances by heat treatment. Inclusions are difficult to contend with, but careful inspection or change of mill supply may serve to control this condition. Corrosion of this type is always attended by formation of pits in the surface of the metal. The pitted appearance is not always caused by galvanic corrosion, however, for small casting defects in cast metal sometimes, appear to be galvanic corrosion pits.

In making a choice of material for chemical equipment, decreasing maintenance cost is not always the primary purpose to be served. Certain chemical compounds decompose readily by contact with metals, some discolor because of a minute trace of a readily decomposed compound and others are lowered in quality because of admixture with corrosion products. The problem of contamination is usually more difficult to solve than that of maintenance. Probably the bulk of contamination cases are handled most successfully by



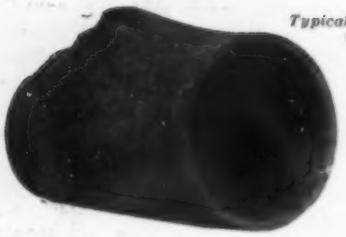
the use of glass, fused silica or enamel-lined equipment. Usually contamination problems can be studied most effectively in the laboratory. Immersion tests are made in which a large surface is exposed of the materials under study, and the conditions of temperature, velocity and the like should be duplicated as faithfully as possible. The presence or absence of light, depending

upon actual plant conditions, becomes an important consideration in this type of test. The observation of results must be chiefly qualitative, although discoloration of liquids can be fairly accurately measured by colorimetric methods.

GREAT progress has been made since the days of the iron-master and his far-removed cousin, the chemist. Metallurgical and chemical engineers are more closely related today by reason of their common problems. The crucible has become an electric furnace and the glass retort has been magically transformed into the high-pressure alloy autoclave.

The list of corrosion-resistant alloys increases daily and the chemical engineer is ever making more pressing demands for new and better alloys. And yet today the brunt of the corrosion in the chemical industries is being borne by a small number of time-tried and reliable metals and alloys—lead, iron, copper, nickel, aluminum. The high-chromium stainless alloys of iron constitute an encouraging portent that the ideal alloy will yet replace some of the old reliables. It will have universal application, both from the viewpoint of corrosion resistance and attractive mechanical properties. The base metal will be lead, iron, copper, nickel or aluminum, but what will give the alloy its noble character? Will it be molybdenum, beryllium, cerium, tantalum or will heat-treatment and melting technique turn the trick? Unborn processes and unrealized process efficiencies await the metallurgist's activities.

EDITOR'S NOTE: *Elsewhere in this issue Mr. Huey briefly reviews modern industrial practice in handling such corrosives as sulphuric, nitric and hydrochloric acids, sulphur oxides, ammonia and ammonium nitrate, alum, acetic acid, caustic soda and various dyestuffs.*



Typical Creep Failure in an Oil-Cracking Tube

Selecting Metals for

HIGH-TEMPERATURE-PRESSURE

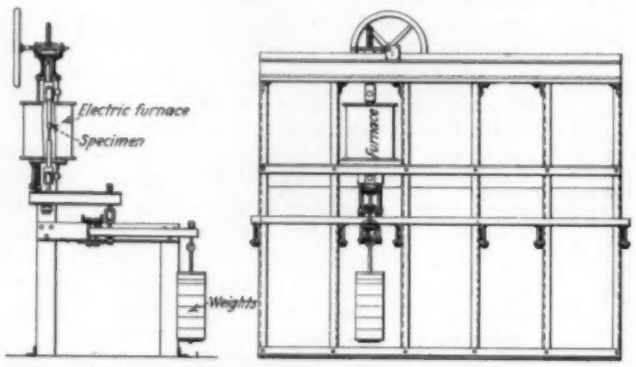
Requirements

By S. D. Kirkpatrick
Editor Chem. & Met.

RECENT and rapid advances in petroleum refining—particularly as regards cracking distillation—have resulted in the use of increasingly high temperatures and pressures. Where ten years ago pressures seldom exceeded 100 lb. per square inch, it is not uncommon today to operate at 750 lb. or higher with temperatures approximating 1,000 deg. F. This progress has been possible only because of improvements in the materials of construction available for use in equipment design and process development.

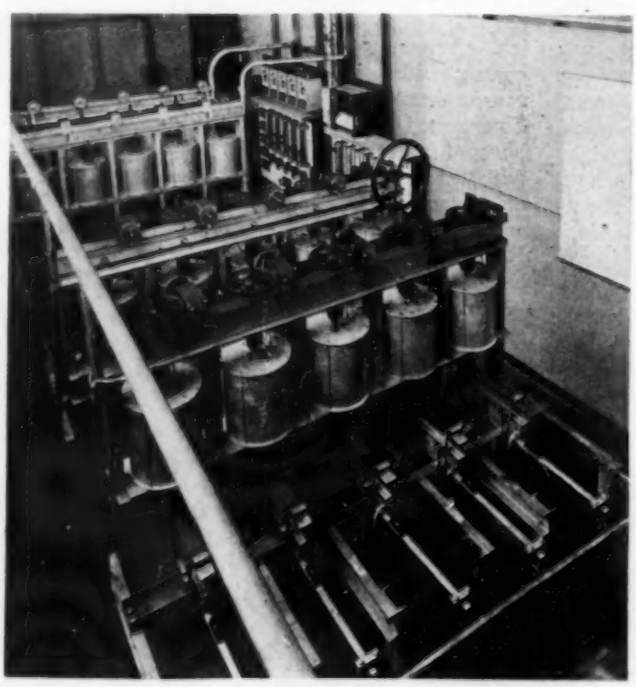
In developing suitable metals for these exacting requirements, as well as determining the usefulness of existing materials, pioneer work—as far as the oil industry is concerned—has been done in the metallurgical laboratory of the Standard Oil Development Company at Linden, N. J. Here, under the direction of R. L. Duff, metallurgical engineer, a staff of specialists has been organized for carrying out exhaustive laboratory, field and service tests of all materials used not only in oil refining but in all branches of the industry — including, of course, this company's more recent work on catalytic hydrogenation at high temperatures and pressures.

An outstanding feature of the work at Linden is the laboratory recently completed for determining the characteristics and performance of metals at elevated temperatures. In a modern cracking still, the most likely cause of failure is the so-called "creep." A tube in the furnace of a cracking still subjected to excessively high temperatures and pressures for an extended period may gradually give way, the walls becoming progressively thinner, until actual rupture takes place. The accompanying photograph shows a typical tube failure caused by creep. Likewise in designing some other types of equipment in which the temperatures or pressures remain practically constant over a long period, it is desirable to know the limiting stress in the material of construction which will produce deformation or creep.



Above—Front and Side Elevations of Equipment for Creep Point Determinations.

Below—Creep Point Laboratory of the Standard Oil Development Company. Twenty Furnaces Are Installed and Five to Be Added.



In order to make certain that the metals used in the refineries of the Standard Oil Company (N. J.) and its various subsidiaries will give safe as well as economical operation, the metallurgical laboratory has determined the basic physical properties of practically all commercially available materials. But these characteristics vary greatly in importance in relation to the design of high-temperature equipment. Ultimate tensile strength, for example, when determined at room temperature, bears no definite relationship to the same property at, say, 900 deg. F. When a specimen is pulled in the usual manner in a tensile machine, the value of the tensile strength determined is, within limits, independent of the rate of loading. At higher temperatures, however, this is not the case, as plastic deformation be-

comes more important and the time element has an important effect. The faster the loading the higher is the apparent strength, while conversely, the minimum value is obtained when the rate of loading is infinitely slow. Given sufficient time, any stress greater than this minimum will break the test piece, so that from an engineering viewpoint it may be unsafe to use the material in a piece of apparatus that is likely to be subjected to stresses of this order. The maximum loading permissible will be some proportion of this minimum stress or limiting creep stress.

In the opinion of the metallurgists of the Standard Oil Development Company, the most important criterion in designing high-temperature equipment is some measure of this limiting creep stress. For their purpose they define it as that stress which will produce 1 per cent elongation in 100,000 hours, 50,000 hours, or 25,000 hours, depending upon the kind of equipment to be built. Creep point determinations are made by suspending weights from a specimen of metal held for a period of 1,000 hours (or longer, depending upon its proposed use) at a high temperature definitely maintained by means of a suitable furnace. The accompanying drawing shows the general design of the equipment, which is based on that developed and used by the Union Carbide & Carbon Research Laboratories. Another photograph shows the present Standard Oil installation of twenty furnaces. Although this is believed to be the largest in the United States, if not the world, it is soon to be enlarged to include twenty-five units.

A wide variety of furnaces and extensometers, different methods of temperature determinations, and tests of various duration have produced many curves and considerable data that are of limited use to the design engineer, because the methods of making these tests are not fully understood. It is believed, therefore, that the following brief description by M. S. Northup, metallurgist in charge of the creep point laboratory, will be helpful to chemical engineers who are interested in the method and the type of results obtained.

The test procedure of itself is comparatively simple, consisting of loading specimens and determining the deformations produced by means of the micrometer device built into the top of the machine. Readings of deformation are to the nearest five-millionths of an inch (0.000005). Measurements of this magnitude are sufficiently small in this type of test because of the length of time involved and the constant load applied. In short-time tensile tests at elevated temperatures, measurements of the order of one-millionth of an inch (0.000001) are necessary even to approximate results obtained in creep tests.

Section of Carbon-Steel Tube Which Failed After 12,000 Hours

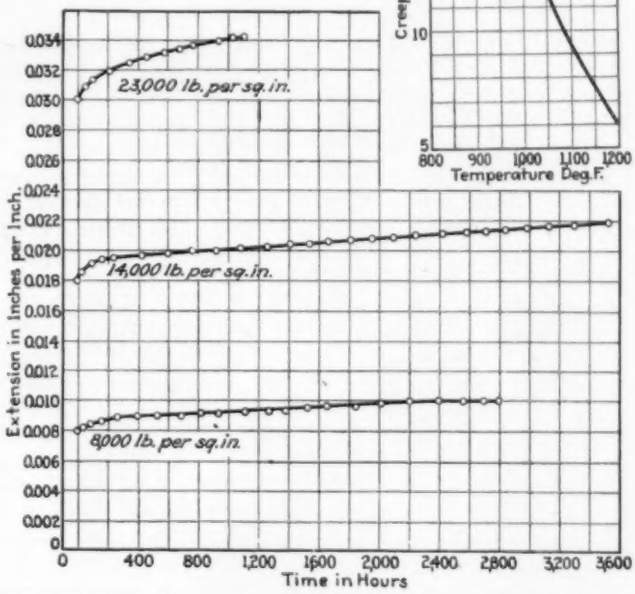
The test pieces are standard 0.505-in. specimens with suitable gripping ends. The reduced section is carefully machined to 0.505 in. diameter with a tolerance of 0.00025 in. plus or minus, and exactly 2 in. between the base of the fillets. The surface is finished with 0000 Hubert paper and is free from scratches or tool marks.

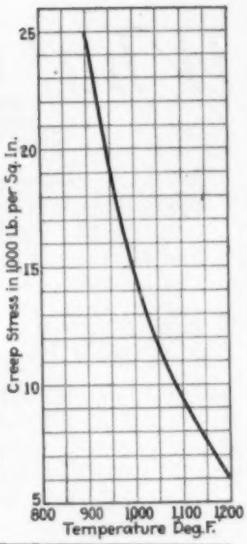
Temperature controllers maintain the temperature of the specimen to within plus or minus 5 deg. F., and the temperature of every specimen is recorded.

Measurements are made on the specimens at stated intervals, the data recorded and the deformations plotted against time. Typical time-deformation curves of a medium carbon steel are shown in Fig. 1. A series of tests at different temperatures is made and the limiting creep stress at each temperature determined. These stresses are then plotted against temperature, producing a curve showing creep stresses for a temperature range. A curve of this kind for a chrome-nickel alloy of the austenitic type is shown in Fig. 2.

Fig. 1 (below) Creep Test on Medium Carbon Steel at 850 deg. F.

Fig. 2 (right) Creep Test on Chrome - Nickel Steel of Austenitic Type





The limiting creep stress, as determined in this laboratory, does not include the initial deformation but is calculated from a portion of the curve wherein the deformation has been sensibly uniform for at least 1,000 hours. Rates of creep for various periods of from two to ten years are determined. This is made necessary by the varying life of different equipment.

In reporting results, the limiting creep stress for various rates of creep and the total deformation during the test are included. With this information the designer can determine safe working pressures commensurate with the desired life of the apparatus. The total deformation sometimes is necessary in designing so that proper allowance can be made in piping and fittings.

In design of equipment it would be unwise to use the full limiting creep stress because of differences in similar materials and other influences impossible to evaluate exactly. The designer, therefore, uses a definite fraction of the limiting creep stress at the maximum temperature for his calculations. It is believed that this method is proving both economical and safe, and far superior to any previous method.

Although creep stresses play a highly important part in design, they alone are not sufficient. Other characteristics of materials are necessary to complete stress calculations, namely, modulus of elasticity, Poisson's ratio, thermal coefficient of expansion, impact value, and corrosion resistance and fatigue.

Considerable work is to be carried on in this laboratory in determining the moduli of elasticity at elevated temperatures and possibly Poisson's ratio. An Amsler hydraulic testing machine, equipped with a load-maintaining device, and a pulsating attachment and a Marten's mirror extensometer will be used in this work. Short-time tensile tests to determine proportional limits at elevated temperatures also will be made.

Much research work on high-temperature impact tests has already been completed, with a program of several months work still to be conducted. A very extensive corrosion investigation, covering a large number of metals, alloys, and protected metals, has been carried on for several years, resulting in data of considerable value.

THIS information is invaluable to the design engineer. It gives definite and reliable data from which proper materials can be selected for practically every condition encountered in an oil refinery, with assurance that metal failures, endangering life and property, will be at a minimum.

For the privilege of bringing this information to its readers, *Chem & Met.* is indebted to Charles H. Haupt, chief engineer of the general engineering department at Linden. Acknowledgment is made also to Messrs. Duff, Thomson and Northup for helpful criticism as well as the various photographs and charts used in the preparation of this brief article.

What CHROME-NICKEL STEELS *Offer To Chemical Engineers*

By John A. Mathews
Vice President, Crucible Steel Company of America, New York

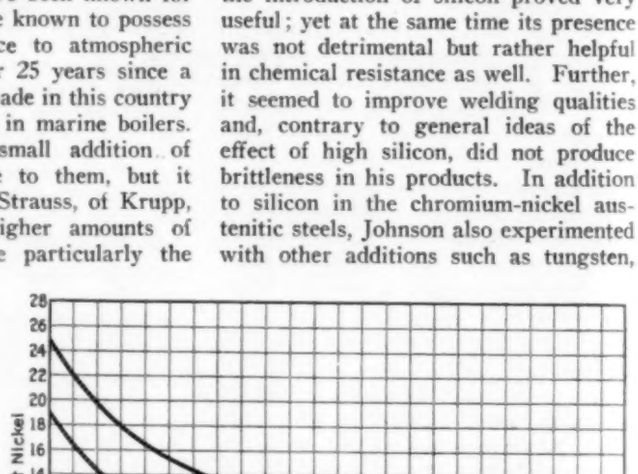
INDUSTRY, within the past two or three years, has become conscious of the inherent possibilities of the austenitic chromium-nickel steels to solve its corrosion problems, and is now rapidly introducing them for materials of construction in nearly all branches of chemical manufacture, food and beverage products, paper making, as well as for decoration and architectural trim. The idea seems to be prevalent that they are new products, but such is not the case, as some of us can testify who have been "watchfully waiting" for nearly 15 years for this recognition and adoption. Our metallurgists saw the need long before industry was ready to create the demand to have its needs satisfied. Only within the past two or three years have we heard producers and consumers talking glibly of "18 and 8" steels—meaning 18 per cent chromium and 8 per cent nickel—and yet we showed that steel at the first Philadelphia Steel Treaters' Exposition about ten years ago.

Many years ago the writer was discussing with the late Prof. John Edson Sweet—that grand old man of the engineering profession—the origin of the pneumatic process for making steel, and I asked his opinion as to the relative claims of Kelly and Bessemer to the invention. In his characteristic droll way he answered, "Well, when Bessemer invented it, it stayed invented." This point of view is applicable to the origin of some of the standard types of corrosion-resistant steels.

THERE are those who begrudge giving credit where credit is due. The claims of Mr. Brearley to the invention of stainless steel have been questioned and instances have been cited of similar analyses made earlier than his steels. One distinguished metallurgist might have been the discoverer of stainless steels had he not tested his products in sulphuric acid, and neglected to test them with nitric. The fact remains that when Brearley started work with his chromium steels he tested them thoroughly, and, furthermore, he foresaw their possibilities and "put them on the map." In other words, when Brearley invented stainless steel, it *stayed* invented.

The ferro-nickels, of 25 per cent and upward in nickel, have been known for over 30 years and are known to possess considerable resistance to atmospheric corrosion. It is over 25 years since a serious attempt was made in this country to use them as tubes in marine boilers. Sometimes a very small addition of chromium was made to them, but it remained for Benno Strauss, of Krupp, to investigate the higher amounts of chromium, and more particularly the effect of lower nickel content, on high - chromium steels.

The nickel steels above 25 per cent nickel are austenitic, but chromium in quantities up to 30 per cent does not produce austenitic steels. A very small addition of nickel to the high-chromium alloys brings about a change to austenitic, and a nickel alloy not high enough in nickel to be austenitic likewise is made austenitic by a relatively small addition of chromium. Professor Strauss (Kruppsche Monatshefte, Aug. 1920) has worked out a diagram of the relationships between chromium and nickel as shown in the curves. In general, it is the steels whose composition is in the upper area that are of most interest from the corrosion-resistance standpoint. Bain and Griffiths (Trans., A.I.M.E., vol. 75, p. 166, 1927) have studied these ranges microscopically, and show the constituents present for a wide range of compositions. Strauss' work was conducted largely during the period of the war and nothing was known of it in this country until about 1919.



Illustrating Influence of Nickel-Chromium Ratio on the Character of Nickel-Chromium Steel

In 1916 Charles M. Johnson, of our company, began an investigation of chromium-nickel steels, including silicon as an essential constituent, and he developed a series of austenitic corrosion-resistant steels before the Strauss steels were known in America. As his first interest was in heat-resisting products rather than corrosion-resistant products, the introduction of silicon proved very useful; yet at the same time its presence was not detrimental but rather helpful in chemical resistance as well. Further, it seemed to improve welding qualities and, contrary to general ideas of the effect of high silicon, did not produce brittleness in his products. In addition to silicon in the chromium-nickel austenitic steels, Johnson also experimented with other additions such as tungsten, molybdenum, copper, cobalt, boron, titanium, and so on. Strauss also worked with other metallic additions to the austenitic base, and has patented one alloy containing molybdenum, especially resistant to sulphur dioxide; and another containing copper, especially adapted to ammonium-chloride evaporation.

It is impossible, in the space available, to deal broadly with the metallurgy of the austenitic chromium-nickel steels. This has been treated in many articles and the outstanding differences between the ordinary carbon and alloy steels and the austenitic steels was discussed by the writer in his Howe Memorial Lecture of 1925 (Trans., A.I.M.E., vol. 71, p. 568, 1925). As regards physical and mechanical properties, these are available in the manufacturers' publications, along with the general chemical resistance of the various products to many reagents.

It is well to be forewarned as to the applicability of the general lists that are

frequently seen. These should be considered only as tentative and suggestive, for many disappointments and misapplications have resulted from accepting them as standard data. The only sure way to determine the usefulness of a particular product for a particular purpose is to try it under working conditions. Unfortunately, laboratory

tests, which have been honestly made by the thousands, will not tell the whole story in many cases; and in many instances the laboratory cannot reproduce the exact conditions existing in a manufacturing plant.

To be sure, some of us have 10 to 15 years of background of laboratory tests and practical application, so that in most cases an experienced maker can make a reasonably good recommendation based upon experience and also in some cases decline to make any recommendation of any existing alloy. It is not necessary at this time to run exhaustive tests of a wide variety of products for use in a well-known and standardized process or operation. Slight departures from standard conditions sometimes make an enormous difference in results and therefore, when possible, we always recommend a practical test.

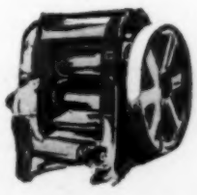
ANOTHER point I would make concerns nomenclature of the austenitic steels. They are designated somewhat indiscriminately as stainless, non-corrosive and corrosion-resistant. In the interest of accuracy and truthfulness, only the last name should be applied. "Stainless" is objectionable because it is primarily a trade or brand name, applicable to the plain chromium alloys produced under the patents of the American Stainless Steel Company. When used as a trade name for the class of products to which it was originally applied it is not misleading. But it is disconcerting to a buyer to procure material under this designation, later to find that under some conditions it does stain or discolor. It may do so, however, in some cases and still be perfectly useful for the purpose intended, if corrosion and pitting are not progressive.

"Non-corrosive" is particularly inappropriate as a general designation, for usually we are dealing with relative resistance and not total resistance. If an alloy is ten thousand times as resistant as ordinary steel, we are still not truthful in calling it "non-corrosive." "Corrosion-resistant" is accurate and consistent with the facts as we find them, and it is urgently recommended that this be adopted as the general designation, even though it be a bit more of a "mouthful" than the other names.

In regard to the reporting of corrosion data, it would be of great benefit to all if a standard method were employed. The simplest to understand and visualize by a prospective user is "inches of penetration per year." Percentage loss by weight doesn't mean a thing unless all samples tested are of the same size and shape; and, unfortunately, that is not possible of attainment. One test is made on sheets and another on bars and the ratio of surface to mass is very different in the two cases. Loss in milligrams per square inch, or other unit of surface, is accurate and easy of duplication in different tests, but the result is not easily visualized in terms of life of a plate or vessel to be made of the material under test.

Turning to the matter of patents, we note that at one time the patent situation in regard to chromium-nickel austenitic steels was quite involved. The matter has been considerably clarified of late, however, by the formation of the Krupp Nirosta Company, which owns a number of patents that, in a degree, were overlapping and duplicating. In 1919 and 1920 patents were issued to Benno Strauss which now have been assigned to the Chemical Foundation. These are composition patents and cover a range of chromium and nickel which is considerably restricted as compared to that covered by the patents issued to C. M. Johnson and P. A. E. Armstrong and others.

Two additional patents were issued to Strauss in 1922 covering the heat treat-



ment of chromium-nickel alloys. These patents have been assigned to Krupp Nirosta. Two patents were issued to C. M. Johnson in 1922 covering a considerably wider range of composition than those issued to Strauss; and in addition they cover the use of high silicon content.

A few years later a somewhat similar patent was issued to P. A. E. Armstrong and R. P. De Vries, of the Ludlum Steel Company, and all of these last three patents have been acquired by the Krupp Nirosta Company, along with several patents of a similar nature. As a matter of fact, with a single exception, all of the special types of austenitic steels which have been developed by our company lie outside of the range of patents controlled by the Chemical Foundation. All of the important patents are now in the hands of either the Chemical Foundation or Krupp Nirosta Company.

It is difficult to understand why our Patent Office should have issued so many patents which in a large measure conflict with and duplicate one another, but since such was the case, it was natural that an effort should be made to combine these patents. Along with the patents, of course, go the combined experience and research of the original companies which were pioneers in these developments.

The chromium-nickel austenitic steels, as originally developed, were of very great use in connection with nitric acid and mixed nitro-sulphuric acid, and had a wide general application in the field of organic acids, food products and salts; but they were not satisfactory in their resistance to the halogen acids or to dilute sulphuric acid. Even though some of them did possess considerable resistance to sulphuric acid, their resistance was not good enough to warrant their commercial use in a great many applications where a need existed for a product which was satisfactorily resistant to dilute sulphuric acid, both at room and higher temperatures.

THIS need claimed the attention of metallurgists, but after much experimenting we have developed in the past year two or three products much more resistant than anything heretofore known in the way of ferrous alloys. These alloys are essentially nickel, chromium and silicon, but in a different proportion from those previously used. They have now been under test in the laboratory, and for a long enough time commercially to make us perfectly sure that they will fill a very important place in the family of corrosion-resistant alloy steels. Their development constitutes the greatest advance that has been made in this field since the original development of those types which are noted primarily for resistance to nitric acid.

Within the range of corrosion-resistant alloys, based upon sufficient chromium and nickel content to render them austenitic, we find products useful in three different fields: First, resistance to chemical corrosion at ordinary temperatures; second, resistance to scaling at elevated temperatures; and third, alloys of high strength at elevated temperatures. The number of different compositions that may be made is unlimited, but experience has limited the production to a restricted number of types. Among these may be found a suitable product for almost any requirement in the chemical and manufacturing industries where halogen acids are not involved.

How CHROME STEELS *Serve the* N

Selecting Metals for a Wide Variety of Severe Service

One of the blending tubs where the nitrocellulose is thoroughly washed to remove all traces of acid. A thin lining of chrome steel alloy greatly prolongs the life of these wooden tanks.

CHROME steel alloys are used by the Hercules Powder Company in equipment for the following operations in the manufacture of nitrocellulose: the production of nitric acid by the ammonia oxidation process, and the handling of strong and weak nitric acid and acidified water. They also find application in equipment for handling treated nitrocellulose.

With few exceptions 18 per cent chromium with carbon below 0.12 per cent is used. Other compositions used are 14 per cent chrome (where lower chrome content gives satisfactory service) and the 18 per cent chrome and 8 per cent nickel is favored where welding is necessary in fabrication. In castings it has been found necessary in some cases to use 26 to 28 per cent chrome and in other cases 18 per cent chrome and 8 per cent nickel.

With our experience in the application of these alloys to the various processes, we developed methods for testing in the laboratory, to determine the corrosion-resisting

Above—A corner in the basement of the nitrating house. The chemical stoneware and chrome alloy pipes carry away the dilute acid from the centrifugal wringers on the floor above. The floor here, which is subject to severe conditions, consists of a cement base or foundation on which bricks have been placed on edge and the spaces between them filled with molten asphalt.

At right—These fans draw the nitrous oxides and acid fumes from the dipping pots and wringers, discharging through the underground duct to the open air several hundred feet from the buildings. The fan blades and housings are of chrome iron.

NITROCELLULOSE *Manufacturer*

By Thos. McKnight
Engineering Department
Hercules Powder Co.,
Wilmington, Del.

A view in the boiling tub house where the nitrated cotton is purified. A section of the top of each tub is provided with a removable lid of chrome steel. Note the maze of piping.

value of the alloys for the uses in which they are to be applied. Numerous tests have been made, and it is well established from these tests that the production of these alloys with better physical qualities than commercial grades of carbon steel and with fairly uniform corrosion resistance, is within control of the steel manufacturer. As corrosion resistance is a vital quality of these alloys we consider the results of corrosion tests a fair basis for acceptance or rejection of chrome steel at the mill.

Usually the material as annealed by the manufacturer has good corrosion-resisting qualities, but we have had instances where parts failed by corrosion in process, while adjacent parts of similar analysis have shown comparatively low loss. Considerable variation in results of corrosion tests has been found in samples from the same plate which had slight variations in heat treatment. Overheating 18 per cent chrome steel without subsequent annealing destroys ductility as well as the corrosion-resisting qualities.

Above—A nitrocellulose wringer and at left a chrome-steel-lined wooden storage bin for nitrocellulose.

Fabrication of chrome steel alloys has developed a new technique in the boiler shop. Accurate fitting is required and shrink fits are used where possible. Rivet holes are drilled and reamed true with minimum clearance for rivets which are carefully heated and driven by hydraulic pressure. Caulked rivets and joints tend to develop leaks and so far welding has not been entirely satisfactory with 18 per cent chrome for strong nitric acid or hot weak nitric acid service.

CHROMIUM IRONS AND STEELS

Exhibit Widely Varying Properties

By Walter M. Mitchell

Assistant Sales Manager, Development Division, Central Alloy Steel Corporation, Massillon, Ohio

IRON-CHROMIUM alloys established their status in chemical industry in 1926, when one of the largest manufacturers of explosives and chemical products selected an alloy of this type for a new nitric-acid plant. This plant required about 200 tons of various apparatus, all made from a high-chromium alloy, a quantity far exceeding anything previously used in any application. This plant has been in operation for nearly three years and has proved so satisfactory that additional and even larger plants have been constructed; now the iron-chromium alloys are recognized as standard for plants of this character.

The corrosion-resisting qualities of alloys of iron and chromium have been known for many years (Armstrong, Proc. A.S.T.M., vol. 24, p. 193, 1924), but no real application of their unique properties was made until 1914, when stainless cutlery was introduced by Brearley in England. A year later patent applications were filed in the United States, and at the same time Haynes filed his application covering a somewhat similar composition. Both applications covered iron-chromium alloys containing sufficient carbon to confer hardening capacity, the alloys hence being suitable only for cutlery, tools, and the like. The high carbon composition of these alloys was more or less unavoidable because of inability of the metallurgist to produce very low carbon ferrochromium alloys required for introduction of chromium into the alloy.

TO UNDERSTAND the iron-chromium alloys, and in particular stainless steels and irons, it is necessary to consider the effect of chromium when added to ordinary carbon steel. Chromium is notable for its great affinity for carbon. It at once combines with the carbon, forming various double carbides of iron and chromium, conspicuous for their extreme hardness. If more chromium is added than required to meet the demands of the carbon, it combines with the iron, forming a solid solution, to which, if the concentration of chromium is sufficiently high, the corrosion-resisting qualities of the alloys are due.

Since chromium increases corrosion resistance, and carbon lowers it, through appropriation of chromium for formation of carbides, it follows that the useful qualities of the alloy depend on the ratio of chromium to carbon content, and on the condition in which the chromium exists in the alloy. When annealed, the stainless steels of Brearley and Haynes consist of a matrix of solid solution in which "free" carbides are imbedded. Heating to a high temperature and cooling, as in quenching, dissolves the carbides, releasing the chromium to useful form and enriching the solid solution. Wherefrom follows the necessity for heat treatment to produce maximum corrosion resistance in stainless steels.

THE HARDNESS of the stainless steels, and the fact that they harden in air while still at a high temperature, limits their workability; and the production of intricate shapes, or even of sheets and plates or tubing, is commercially impractical. Recognition of the desirability of a metal with the corrosion resistance of heat-treated stainless steel, but with working qualities of mild steel, led to the development of the "stainless irons." Introduced in about 1920, these were made possible through the production of ferrochromium alloys of very low carbon content, so that entry of excessive carbon into the alloy was avoided. This was a signal advance, for carbon was maintained so low that heat treatment was not required to produce corrosion resistance, and the alloy, while not as soft as mild steel, was nevertheless soft enough to be workable into all forms.

Stainless alloys with chromium above about 14 per cent and with very low carbon show marked differences from the stainless steels. As shown by Bain (Trans., A.S.S.T., vol. 9, p. 9, 1926), Monypenny ("Stainless Iron and Steel," London, 1926, p. 89), and others, the change in analysis is accompanied by lessened tensile strength, a considerable increase in ductility and a nearly complete loss of hardening capacity, no matter what the method of cooling.

Such alloys are rather peculiar from the metallurgical standpoint in that they show no critical temperature, and consequently, phase change or recrystallization does not take place as with ordinary carbon steel. Still further increase in chromium content (20 per cent or over), up to reasonable limits, introduces no marked change if carbon is maintained low. If carbon is increased with chromium, the alloy increases progressively in hardness, but without becoming susceptible to heat treatment. The high-carbon, high-chromium alloys are very hard, respond only slightly to annealing treatment and are practically unmachinable and can be produced in the form of castings only. Thus, the important ratio of chromium to carbon content not only determines the degree of corrosion resistance but the physical characteristics as well.

APPRECIATION of the effect of other elements in modifying the characteristics of iron-chromium alloys in certain directions is shown by various patents. Among these are the Armstrong patents, granted 1919-1924, for ferrous alloys containing significant amounts of chromium, silicon and carbon for which "high surface stability" was claimed; the Skelley patent of 1923 covering additions of molybdenum; the De Long and Palmer patent of 1924 covering additions of copper, etc. Mention should be made of the alloys of iron-chromium and nickel introduced about fifteen years ago in Germany by Strauss and now commercialized in the United States by the Krupp Nirosta organization, and the Johnson patents adding silicon to the iron-chromium-nickel combination, producing the Rezistals. The iron-chromium-nickel alloys are highly important, but, falling outside the iron-chromium analyses, are to be discussed in detail elsewhere.

As a result of variations in physical characteristics because of additions of other elements and the restriction of analysis ranges by patents, the iron-chromium alloys group themselves

roughly into several classes, as follows: (1) *Stainless Steels*—Iron-chromium alloys containing sufficient carbon to confer hardening capacity, and requiring heat treatment for development of proper corrosion resistance. (2) *Mild Stainless Steels*—Originally classed as stainless irons because of lower carbon content, but possessing distinct hardening capacity; heat treatment desirable but not necessary for development of corrosion resistance. (3) *Stainless Irons*—Alloys with over 16 per cent chromium and very low carbon, with or without small additions of other elements. Practically no capacity for hardening. (4) *Chrome-Irons*—Alloys containing upward of 20 per cent chromium, with or without small additions of other elements. These classes are now considered in more detail.

Stainless Steels—The original analysis of Brearley, which is still adhered to for cutlery purposes, contained 0.30 per cent carbon and 13 per cent chromium. For certain purposes, where even greater hardness is required, the original analysis has been altered by increase in both carbon and chromium, and we have steels with from 0.65 to 1.5 per cent carbon, and chromium up to 18 or 20 per cent. These all harden on air-cooling and are notable for their great hardness and wear-resistance. They, however, lack ductility and toughness. They are used for cutting tools, dies, and the like, and for parts of equipment where resistance to wear and abrasion, together with a considerable degree of resistance to atmospheric and chemical attack, is desired.

CHEMICAL industries have used them for valve parts for high-pressure steam lines, for oil-refinery and nitric-acid plant equipment, for pump plungers for ammonia-synthesis compressors, and so on. These steels do not soften materially at temperatures under 950-1,000 deg. F., which gives them considerable advantage over carbon steels when hardness and wear resistance are necesary. A number of these steels are sold under commercial trade names, as Carpaloy 2, Crucible Stainless A, Firth-Sterling Type A, for example, and the higher carbon high-chromium steels as Midvale Diamond Brand, Firth-Sterling Type B, Crucible Stainless B, Delhi Hard, Neva-Stain, and so forth.

Mild Stainless Steels—The composition of this class is rather narrowly restricted to 12, 14, or 15 per cent chromium, with carbon under 0.12 per cent or in some cases, where greater hardness is desirable, under 0.18-0.20 per cent. This is the original stainless iron and was heralded on first appearance as non-hardening. It was soon found, however, that the alloy had distinct hardening properties and was better classed as a steel than as an iron. This analysis is *par excellence* the more desirable where high tensile strength and toughness, combined with ductility, are desired. This is a considerably softer metal than the preceding class and is produced commercially in all forms. It has been adopted by the U. S. Navy Department as standard for steam turbine blading and shrouding, a service requiring high strength and elasticity, together with toughness and machinability.

WHILE LACKING the highest resistance, it finds many uses in chemical and petroleum industries, and has been used successfully for nitric-acid equipment where the more concentrated acids are handled. Its high strength and toughness make it suitable for bolts, nuts and studs which must be corrosion-resistant. It holds its strength well at elevated temperatures and will resist scaling at temperatures under 1,500-1,600 deg. F.

While there is a certain percentage of free carbide present in annealed material, the ratio of chromium to carbon is sufficiently high to avoid the necessity of heat treatment for development of corrosion resistance. The metal is distinctly air-hardening, Brinells of 352-444 being easily obtainable, depending on the section of the piece. This property makes the metal less desirable for riveting and welding operations than the true stainless irons, unless the work will admit of subsequent annealing. Typical commercial alloys of this analysis are Central Alloy's Enduro S and Enduro S-15 (carbon under 0.18 per cent); Crucible's Stainless 12; Ascoloy 33; Firth-Sterling Type T; Carpaloy 1; Uniloy 1409.

Stainless Irons—The customary analysis range of this class is 16-20 per cent chromium with carbon under 0.10 or 0.12 per cent, with or without small additions of other elements such as silicon, copper, and molybdenum. As the ratio of chromium to carbon is high, these alloys show virtually no hardening capacity (a Brinell of 200 is about the highest obtainable) and they show excellent corrosion resistance under any condition of heat treatment. They are quite ductile, easily worked both hot and cold, reasonable in cost and may be regarded as the best of the straight iron-chromium alloys from the standpoint of general utility. Since the alloy has no hardening capacity, the sole method of increasing hardness and tensile strength is by cold working, which of necessity lowers ductility.

In alloys produced under Armstrong patents, such as Enduro Type A, silicon is increased to 1.10 per cent maximum. There has been much discussion regarding the effect of silicon and its advantage. There is little doubt that it increases resistance to scaling at high temperatures and reduces air-hardening tendency, acting somewhat similarly in this respect to increased chromium. Its effects on corrosion resistance seem to be generally favorable, but not against all agents: strong solutions of alkalis attack more readily. Unfortunately, silicon's advantages are counterbalanced by increased tendency to grain growth at high temperatures and reduced impact strength, although this latter may be kept reasonably high by proper processing. The addition of about 1 per cent copper to 20 per cent chromium, as in Carpaloy 3 (produced under De Long and Palmer patents), tends to increase resistance to halogen compounds and, in particular, to sea water and brine (Strauss and Talley, Proc. A.S.T.M., vol. 49, p. 217, 1924).

Alloys of this class require some care in handling, and excessive temperatures should be strictly avoided because of the ever-present tendency toward grain growth (characteristic of all high-chromium iron alloys) with loss in ductility, impact strength, and so forth. This is, however, not accompanied by increase in hardness no matter how high the temperature or how rapid the rate of cooling. Since there is no phase change or recrystallization, coarse crystalline structure, once established, cannot be removed by any known method or treatment, other than mechanical working. This peculiarity of all high-chromium alloys with low carbon intrudes objectionably in welding operations, producing a somewhat brittle weld which cannot be greatly relieved by annealing. For fabrication of annealing boxes, retorts, and kilns, where temperatures will not exceed that of scale resistance (about 1,600 deg. F.) and where strength or toughness are of no great moment, welding may be considered satisfactory.

THE GREATEST application of these alloys has been in plants for making nitric acid by the oxidation of ammonia (Mitchell, Trans. A.S.S.T., vol. 15, p. 303, 1929). This development, which established the usefulness of the iron-chromium alloys, has practically revolutionized the manufacture of this important acid. In all, some 4,000 to 5,000 tons of equipment has been installed in the last three years, representing an investment of upward of $5,000,000.

In addition to nitric acid, this class successfully resists the milder organic acids present in fruits and vegetables and, in consequence, has been used for canning and preserving machinery, dairy and milk-handling machinery, as well as for kitchen and cafeteria equipment. Its brilliant and permanent luster, and the satisfactory service given in many installations, is making it a strong

competitor of nickel, Monel metal and other nickel alloys.

Objections have been raised to the use of these alloys for plant equipment fabricated by riveting on account of low impact strength and grain growth when subjected to high temperatures. Such objections appear to be ill-founded. Actual experience in nitric-acid plants shows that riveting may be done with every assurance of stability and that such riveting will remain absolutely tight without further attention.

There are a number of alloys of this class on the market, the more important being Enduro A and Enduro AA (the latter with low silicon), Crucible Stainless Iron 18, Defirust, Ascoloy 66, Unioloy 1609, and so on.

Chrome Irons—Alloys with a minimum of 20 per cent chromium produced largely under Becket patents constitute this class. They are produced both as rolled products and as castings, the latter providing the greater tonnage. Similar to the preceding class, the low-carbon alloys are virtually without hardening capacity and are not susceptible to heat treatment. With carbon exceeding 0.50-0.75 per cent, the alloys become increasingly harder. They are not susceptible to heat treatment, however, and are only slightly softened by annealing. In alloys used for wear and abrasion resistance, carbon will run from 2.25 to 2.75 per cent. Such alloys are exceedingly hard and obviously can be supplied as castings only.

THE GREATEST application of chrome irons is in heat-resisting castings, such as for furnace parts. Macquigg (Trans., Am. Inst. Chem. Eng., 1926) shows that resistance to oxidation and scaling increases with chromium content, reaching a maximum at about 20-22 per cent chromium, and that alloys of this analysis may be used at temperatures as high as 2,100 deg. F. for long periods without deterioration from scaling. Owing to the tendency to grain growth and impairment of physical properties, these alloys are not always safe metals when heavy stresses are to be maintained at high temperatures. The chrome-nickels with added silicon or tungsten are more suitable for such applications.

Considering corrosion-resisting properties, these high-chromium alloys show generally higher resistance than the third class. They are, however, more difficult to handle in fabricating operations and may occasionally show laminated structure in sheets and plates. One important property of these alloys is their excellent resistance to sulphur and sulphur gases at high temperatures. There has also been some interest in rolled products of this class for resistance to mixed acids, but results obtained are somewhat erratic, and the chromium-nickel alloys with very low carbon appear to be more reliable in cost cases.

Alloys of this analysis are sold under trade names such as Duraloy A, Sweetalloy 19, Crucible Stainless Iron 24, and Ascoloy 55.

CONSIDERING the chromium alloys as a whole, their outstanding characteristic from the corrosion-resisting standpoint is resistance to nitric and nitrous acids, oxidizing agents in general, sea water, fresh water, mine waters, organic acids, foodstuffs such as fruits, vegetables and dairy products, gasoline, petroleum and petroleum products, sugar solutions, alkaline solutions, ammonia, and so on, it being understood that the degree of resistance is determined by the chromium content of the alloy. As a whole, the alloys are highly resistant to sulphur and sulphur compounds, having considerable advantage over nickel and nickel-rich alloys in this respect.

They are not resistant to sulphuric acid (unless of high concentration) nor to the halogen acids and the majority of the halogen compounds.

Thermal conductivity of the chromium alloys and of all heat-resisting alloys is low, averaging less than half that of steel or iron. The effects probably are negligible with sheets or thin plates where the condition of the surface may be a more potent factor in retarding heat transfer. In heavy sections, however, the low conductivity may prove objectionable, but in some operations, the slow intake of heat will be counterbalanced by the equally slow loss of heat which follows in cooling. The coefficient of thermal expansion is slightly less than that of steel and this usually is advantageous, particularly in equipment which may be subjected to fluctuating or widely varying temperatures.

SUMMARIZING briefly the important characteristics of the several classes of chromium-iron alloys, we may says that:

Stainless steels, Class 1, and high-carbon alloys of Class 4 are notable chiefly for hardness and wear-resistance and are suitable for applications where such properties are desired. The stainless steels require heat treatment for development of useful physical and chemical properties.

Mild stainless steels, Class 2, are notable for high physical properties, such as tensile strength and toughness, combined with machinability and ductility, and are useful where strength and toughness are more important than corrosion resistance.

Stainless irons, Class 3, are alloys of lower strength but of higher ductility and corrosion resistance. They are to be used when such qualities are of more importance than tensile strength. They do not require heat treatment for development of useful properties.

Chrome-irons, Class 4, are of greatest importance for heat resistance, and in the higher carbon ranges for resistance to wear and abrasion.

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HIGH-CHROMIUM
Cast Steel Flue Becomes Severely Brittle

By J. D. Davis

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IN THE COURSE of experiments in coal carbonization now in progress at the Pittsburgh Experiment Station of the U. S. Bureau of Mines, the need developed for a material of high thermal conductivity for construction of heating flues. Resistance to oxidation at temperatures around 1,100 deg. C. also was required. A high-chrome (chromium, 32 per cent; carbon, under 0.25 per cent; nickel, 6 to 8 per cent) steel was recommended for the purpose, and this was used in cast form.

In use the flues were rapidly heated to 900-1,100 deg. C. and maintained at this temperature 5 to 7 hours, after which they were allowed to cool to room temperature, the time required being approximately 18 hours. Owing to the large quantity of heat stored in the refractory setting in which the flues were placed, and its high insulating properties, the cooling was slow. After 10 heats under these conditions it was noticed that, while there was scarcely a trace of oxidation of the high-chrome steel, it had become very brittle and some of the pieces had cracked. Attempts to repair the cracks by welding in an oxyacetylene flame only resulted in further cracking, and the metal was so hard that it could not be machined at all.

A large tube (13 in. in diameter by 26 in. long, with 1-in. wall) of the metal is still in use after twenty heats and has not developed cracks. It is very hard, however, and probably would not resist shock well.

It may be concluded, therefore, that cast high-chrome steel is not an ideal material to use when the service required involves alternate heating and cooling in contact with flue gases. The embrittlement may be due to carburization by carbon monoxide, and if excess air were maintained in the gases, less embrittlement might take place. Resistance of the metal to oxidation is very high.

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Cheaper
LOW ALLOY STEELS
for Numerous Applications

By Jerome Strauss

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IN THE CONSTRUCTION of equipment for the chemical industries it has been rather common practice, when carbon steels and cast irons would not satisfactorily serve, immediately to apply, sometimes without thorough study, highly alloyed steels such as "stainless" iron, high-chromium irons, high-chromium, high-nickel steels, nickel-base alloys and similar materials of rather high initial cost. In many cases the conditions of service warranted such drastic measures and the accompanying expenditures, but there are many applications where these highly alloyed steels are not a necessity, and steels lower in alloying elements would amply serve the needs of the chemical engineer, functioning at lower cost for a period of time compatible with the rate of obsolescence of the equipment.

In some processes also, size and intricacy of individual parts necessitates greatly revised equipment design when applying these iron-chromium and iron-chromium-nickel alloys. Quite too little attention has been paid to the "intermediate" alloy steels. However, desirable properties, both at atmospheric temperature and at temperatures appreciably above, have now caused their application to extend at a fairly rapid rate.

One of the earliest alloy steels to be used, when only mildly corroding conditions prevailed, was the 0.20 per cent carbon–0.25 per cent copper steel employed largely in the form of sheets. As a result, however, of many practical observations and the very exhaustive sheet-testing program carried out by the American Society for Testing Materials, it has been definitely shown that this steel is limited in utility to mild atmospheric exposure. In the presence of even a highly sulphurous atmosphere, but more particularly when immersed in natural waters, no advantage is shown over carbon steel sheets.

A later development has been the use of simple steels containing 1 per cent copper, and this material is finding much use as oil lines and other piping in moist soil and under water. Still further improvement in copper steels is indicated by compositions within the range of 0.5 to 1 per cent copper, with 1 to 4 per cent chromium and appreciable quantities of silicon.

Nickel steels containing from 2 to 5 per cent nickel have proved very advantageous in many types of service, the outstanding applications being the use of the lower-nickel-content material in construction of locomotive boilers; and those richer in the added element in equipment for the evaporation of caustic. In the former instance, the increased strength at operating temperature, as well as the increased corrosion resistance, is significant.

Chrome-nickel steels have been used to a very great extent. In Europe, in the construction of equipment for the synthesis of ammonia, low-carbon steels containing approximately 4 per cent nickel and 1 per cent chromium have been successfully employed, although they are giving way at the present time to chromium-vanadium steels for this service. While carbon steels are still paramount in castings for moderately high-temperature service up to about 350 deg. C., as in steam-generating stations, oil refining and so on, their load-carrying ability is not entirely acceptable to the designer for service above about 300 deg. C. Hence for higher temperatures they have given way to forged carbon steels or low-alloyed steels, either cast or forged.

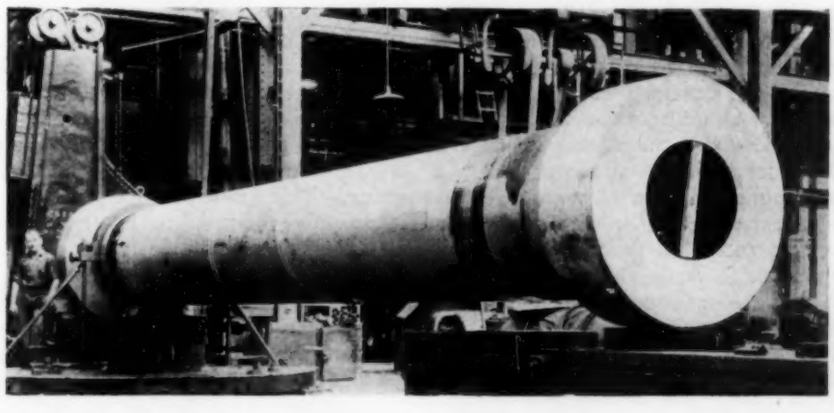
It is possible, of course, and too frequently the usual procedure, when stresses at elevated temperatures are beyond the range of carbon steels or weights in the latter would not be permissible, to turn, as previously noted, to the highly alloyed steels. Some of the low-alloy steels, however, possess at moderately elevated temperatures (up to about 600 or 650 deg. C.) resistance to deformation equally as good as that of many of the costlier steels accompanied by sufficient resistance to some corrosive mediums to make them exceedingly desirable construction materials. A very large production of valve bodies and valve parts such as spindles and bolts has resulted in steels containing 1 to 1½ per cent Ni and ½ to ¾ per cent Cr.

For these same classes of service, a chrome-vanadium steel containing 1 per cent to 1.5 per cent chromium and 0.2 per cent vanadium also has been eminently successful, not only because of exceptional strength properties at the moderately elevated temperatures employed but due as well to its having withstood satisfactorily the accompanying moderately corrosive conditions.

The same steel, because of its highly suitable welding qualities and ease of casting and forging in the production of large hollow vessels, as well as due to the strength and mild corrosion resistance just noted, stands alone among the alloy steels in reaction chambers for the synthetic-ammonia and the oil industries. A feature of this steel is the uniformity of its properties with the use of only ordinary manufacturing refinement.

A few other alloy steels have served to a minor degree. For better resistance to the atmosphere and other very mild corroding mediums, a steel containing 0.5 per cent copper and very small quantities of molybdenum has been used, but its limitations are those of the plain copper steels. Carbon steels with a molybdenum addition have good strength properties at elevated temperature but possess no special advantages over carbon steel in meeting corrosive attack. The known strong air-hardening properties imparted by this element, moreover, would debar it when certain fabricating methods are required. Manganese steels with 1 to 2 per cent of this element are moderately well suited to elevated-temperature service, but afford

Chrome-Vanadium Steel Catalyst Chamber for Ammonia Synthesis



no improvement over carbon steel in the presence of corrosive mediums, unless these be sea water or some natural waters where their use has been successful.

It is perhaps well also to mention the chromium-aluminum steel, with small amounts of other elements, which acquires a hard and corrosion-resisting surface when "nitrided" by decomposing ammonia. No doubt many uses for this steel will be found in chemical-engineering equipment, especially where hardened surfaces are required, such as in pump parts. For large members, however, or parts in which a brittle surface is objectionable due to deformation, the present "state of the art" prohibits its employment.

Recapitulating then, the lower alloy steels are of value in chemical engineering when certain mildly corroding mediums are present, when high strength up to about 600 deg. C. is required, or when both conditions, combined with good fabricating qualities, are essential. According to the service, chrome-vanadium, nickel or nickel-chrome steels are most successfully applied.

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Weak Sulphuric Acid Yields to NICKEL-SILICON STEELS

By W. B. Earnshaw
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PRACTICALLY all of the available acid-resistant materials of construction possess, unfortunately, certain undesirable qualities. Materials capable of extreme resistance to a wide variety of corrosives do not possess good physical qualities and are difficult to machine and fabricate, while those with better physical qualities are limited in their resistance to a comparatively few corrosive conditions.

A new type of nickel-silicon steel, however, presents a development toward a material possessing remarkable acid-resisting properties combined with excellent physical characteristics.

Working along parallel lines, the Crucible Steel Company of America and the Duriron Company have succeeded in developing a steel which was primarily designed for resistance to hot, weak solutions of sulphuric acid. Several grades of this steel are now being produced in the form of hot- and cold-rolled bars, sheets, plates, shafting, wire, rivets, bolts, nuts and castings.

The rolled grades show ultimate tensile strength of from 90,000 to 110,000 lb., and are extremely ductile. Castings will show an ultimate tensile of approximately 75,000 lb. per square inch. The alloys are all of the austenitic type and non-magnetic. The austenitic feature is an extremely important one with regard to successful welding of chemical equipment. With either oxyacetylene or arc welding there is no appreciable difficulty in making good welds, either from a mechanical standpoint or from the standpoint of resistance to corrosion. The composition and structure of the weld is practically the same as that of the original stock, and in a large number of service and laboratory tests no evidences of differential corrosion have been detected in either the weld or the sheet.

The inherent ductility of this steel allows the use of a wide variety of methods of fabrication, such as double seaming, riveting, caulking, forming and deep drawing.

At the present time this steel is offered in three grades. The A grade has a nickel content of 25 per cent but contains no chromium. The B grade has a considerably higher nickel content and a chromium content of about one-third that of the nickel. Silicon content of both grades is about 5 per cent. The D grade, which is at the present time offered only in the form of castings, contains approximately 15 per cent nickel and lower percentages of silicon and chromium.

In regard to chemical resistance, the B grade has by far the widest range. It is not only extremely resistant to the lower concentrations of sulphuric acid at the boiling point but is equally resistant to pickling solutions containing appreciable percentages of ferric sulphate. This grade also has proved unexpectedly resistant to nitrous vitriol and to nitric acid even when containing small percentages of chlorides.

The B grade may prove to be a valuable material for the construction of equipment to resist boiling glacial acetic acid, as the general class of alloys in which the chromium content considerably exceeds the nickel is usually extremely resistant to acetic acid corrosion.

The Durimet A and D grades show practically the same resistance to weak, hot sulphuric-acid solutions as the B grade but are not nearly as resistant to many other solutions. They are, however, excellent materials for resistance to weak acetic acid, aluminum sulphate, ammonium sulphate, boric acid, calcium hypochlorite and the majority of the sulphates with the specific exception of copper sulphate. The A grade, containing no chromium, shows excellent results with chromic acid, whereas the other grades, containing chromium, are not suitable. The A and D grades will not resist nitric acid or atmospheric corrosion, and none of the grades of Durimet should be considered as resistant to hydrochloric acid with the exception of very weak cold solutions.

The sponsors of these steels are very frank in admitting that while a few service tests have been under way for about eight months, most of the recommendations and statements regarding the chemical characteristics of Durimet are based on laboratory depreciation tests, and should be considered only with the full realization that such laboratory tests are only valuable in indicating what conditions should or should not be considered for making extensive service tests.

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STAINLESS *Mirror Used In Photography of Explosion Waves*

By G. St. J. Perrott
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AN APPARATUS has been constructed at the Explosives Experiment Station of the U. S. Bureau of Mines at Bruceton, Pa., for photographing the pressure waves produced by detonating charges of dynamite. In this work it was necessary to employ an 18-in. spherical mirror capable of withstanding the severe concussions attendant on the experiments and of retaining its reflecting power and optical surface under outdoor weather conditions.

The blank for the mirror was finally made from a forging of stainless steel which was then ground into an optical surface by the Brashear Instrument Company, of Pittsburgh. The mirror has been in constant use for more than a year and has shown no evidence of corrosion or loss of reflecting power.

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Low-Cost Corrosion Resistance with ALLOYED CAST IRON

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CHEMICAL INDUSTRIES are among the greatest sufferers from loss by corrosion or deteroiration of metals in service. As usual, the loss is greatly increased by interruption to production, aggravating delays and emergency measures to insure maintenance, rather than by the initial cost of the material involved. From these difficulties, alloyed cast iron offers some degree of relief at very little cost. The common elements, silicon, nickel, chromium, copper, molybdenum, and manganese, are the most important available for alloying.

In every case the effects which alloys exert from the metallurgical standpoint upon cast iron must be taken into account, because the production of a casting containing, for example, 4 per cent of copper or 2 per cent of chromium, will so alter the usual pouring, machining, and associated properties essential to cast-iron production, that the product can no longer be recognized as cast iron.

In this paper only gray iron will be kept in view, since other types such as malleable or white cast iron occupy special fields of application.

ELEMENTS common to cast iron are carbon, silicon, manganese, phosphorus, and sulphur. A certain balance between these elements is necessary for castings of different sizes and sections and this balance is commonly obtained by varying the silicon content.

The composition range of the common elements in cast iron follows:

Total Carbon	3.10-3.40
Silicon	0.60-3.00
Manganese	0.35-1.00
Sulphur	0.06-0.12
Phosphorus	0.06-0.75

Of these manganese and sulphur exert little effect in the ranges indicated, except in special cases. The carbon range is comparatively narrow, i.e. within ± 5 per cent with an average of 3.25. Phosphorus and silicon are spread over a broad range but these two elements can be put under close control by a judicious selection of materials for the cupola charge.

The common elements form micro constituents which profoundly affect the general properties and corrosion resistance of cast iron. Usually manganese and sulphur are completely dissolved in the matrix or present in such minute proportions as manganese sulphide as to cause no concern. Phosphorus, if in excess of about 0.30 per cent, may occur as a carbon-rich phosphide which may interfere with mechanical properties or corrosion resistance. The silicon is apparently dissolved in the matrix and carbon is partly dissolved, as well as present in several forms of graphite plates, or segregated into carbides. These micro constituents exert considerable influence upon the susceptibility of an iron to a general corrosion as well as to galvanic action, pitting, and deterioration.

WHEN elements are added, due allowance for their effects must be made, although it is customary to use them in such a way as to secure a correct balance where the silicon content is not changed, or cannot easily be changed because of production requirements. Having determined a suitable composition, it is a comparatively simple matter for an up-to-date foundry to produce the material.

Chemical engineers in some branches of their industry have seen the wisdom of specifying the composition of their castings; and in most cases where corrosion is the dominant factor, a specification covering the composition of the iron usually serves the purchaser adequately. The elements listed in such a specification usually consist of the range of silicon desired and such alloying elements as are desirable, because the remaining constituents in cast irons, with the exception of phosphorus, usually occur in uniform quantities and are not detrimental. If strength, hardness, or wear resistance are dominant factors, an amplification of the specifications can be provided.

CORROSION is the enemy of metals which causes the greatest concern in the chemical industries. In so common a material as soil pipe, which has an estimated life of 20 to 25 years, an increase in this average life of one year means a tremendous saving to the consumer. In other cases, as in oil refining for example, a corresponding degree of improvement could be measured in a period of a few months. It is to alloying materials that the metallurgist must turn if he would effect such improvement.

The influence of alloying elements would be most effective, it would seem, if the ferrite or pearlite constituents of cast iron were reinforced to resist corrosion. This accomplishment is limited by the solubility of such elements as silicon, nickel, chromium, copper, and manganese in the solidified iron and their effects upon castability, machinability, and other physical properties. Of these elements only nickel is completely soluble in the solid; silicon somewhat less so and copper only to a limited extent. Chromium, manganese, and molybdenum are carbide-forming elements and can only be used in small amounts before segregation into carbide formations interferes with mechanical or physical properties.

The silicon and nickel contents are limited only by the effects produced upon mechanical properties. Less than 3 per cent of silicon must be present to insure machinability and in the case

of nickel less than 6 per cent or more than 14 per cent. Copper in most cases merely exerts a neutral or indifferent effect. Manganese, chromium and molybdenum are carbide-forming elements and exert powerful effects.

Silicon—It will be valuable to consider the alloying elements separately. Silicon, if considered as an alloying element and used in quantities in excess of the usual amount, may be expected to decrease corrosion in tap water and sea water, and to increase corrosion in soil, acid and alkaline solutions. Forrest (H. O. Forrest, A.S.T.M., 1929) points out the possibility that silicon up to 4 per cent and nickel up to 14 per cent will markedly improve the corrosion resistance of cast iron in tap water. Tests made in New York harbor water indicate a decreasing resistance in sea water with decreasing silicon. Data upon the "graphitization" of cast iron in soil corrosion have been collected by Speller ("Corrosion—Causes and Prevention," McGraw-Hill Book Company). Since silicon in excess causes the precipitation of free ferrite, and galvanic action between graphite and ferrite in soil-water electrolyte is more rapid than between graphite and pearlite, it may be expected that a silicon excess would encourage graphitization. Delhart (*Comp. Rend.*, vol. 181, 1929, p. 786) reports increased corrosion in acids as silicon rises to 4 per cent and low silicon contents are emphasized by others.

Nickel—Nickel reduces corrosion in tap water, soil, sea water, acid and alkaline solutions. Nickel may, in general, be substituted for silicon to secure the proper degree of graphitization and better corrosion resistance in many irons where silicon is an undesirable constituent. Improved resistance to tap-water corrosion for irons containing up to 14 per cent nickel has been suggested above, and this relation as well as the progressive improvement for small additions up to 5 per cent nickel has been confirmed in laboratory tests. Very low silicon irons, kept gray with nickel additions, suggest an effective improvement against sea water or brines. Piwowarski (Kotzchke and Piwowarski, "Archiv für das Elsenhüttenwesen," Vol. 2, Nov., 1928) reports an improvement in ammonium sulphate solutions.

PREVENTING ferrite by replacing some of the silicon in cast iron with a compensating amount of nickel shows promise of improving resistance to soil corrosion and, in general, where silicon in excess is deleterious. In acid corrosion, nickel additions of one per cent or less seem to produce the best results. In alkaline solutions, the agreement that nickel additions improve resistance is general, and data now being accumulated tend to confirm this situation in many cases. Large additions of nickel, in the 15 to 20 per cent range, combined with copper or chromium, reduce corrosion in practically all of the above corrosives to a fractional amount of that occurring when plain cast iron is used.

Copper—Copper seems to be effective against acid solutions, sea water, and atmospheric attack; but it is dormant or actually detrimental in tap water, distilled water and alkalis. Rolfe (R. T. Rolfe, *Iron & Steel Ind.*, May, 1929) reports improvements in mine water, sea water, and dilute acids, but notes a decreased resistance in tap water.

LIMITED solubility of copper in cast iron prevents application in appreciable quantities. From the metallurgical standpoint this limit can be expanded by the use of nickel or molybdenum additions wherever higher alloy contents, in which copper is an important factor, are desired.

Chromium—Chromium, in small additions, is effective against tap water, sea water, and weak acids. Donaldson (J. W. Donaldson, *Foundry Trade Jour.*, 1929, p. 489) reports improvement in corrosion from sea water or strong acids, and slight improvement in the case of tap water, weak acids and ammonium chloride. Piwowarski reports similar results and points out the effectiveness of larger amounts of chromium in the neighborhood of 1 per cent, which, however, produce unmachinable irons. He concludes that a machinable nickel-chromium iron of about 2.5 per cent nickel with 0.5 per cent chromium solves this particular situation.

COMBINATION of nickel and chromium (ratio usually two or three parts of nickel to one of chromium) preserves the machinability of cast iron and presents prospects of improved corrosion resistance for many applications. Installations of chemical equipment for which nickel-chromium compositions, ranging from 1.0 per cent nickel and 0.30–0.50 per cent chromium to 3.0 per cent nickel and 0.75–0.90 per cent chromium, are specified and in current use, followed upon plant tests under operating conditions. Nickel-chrome additions in smaller amounts are being employed as frequently to improve the physical quality of castings—an effect which often is accompanied by, or is responsible for, improved resistance to corrosion. Two manufacturers of pipe offer a nickel-chrome alloyed iron, cast by processes which give the product greater ductility and tensile strength, and also, due to the close grain structure, greater corrosion- and erosion-resisting qualities than ordinary gray cast iron.

Manganese, in the usual quantities present in cast iron, apparently exerts very little influence upon corrosion properties. In larger amounts Delhart reports increased attack by acids and Haase mentions its tendency to turn alkalis brown.

Molybdenum is being offered for various services requiring corrosion resistance but little published data upon its performance in cast irons is available.

STUDY of growth, scaling and strength of cast irons at elevated temperatures embraces a field that seems to have attracted more notice than corrosion. As in corrosion, the results require a definition of service conditions, such as temperature atmosphere and duration of exposure, before a generalization is possible for the guidance of the engineer. In general, the trend favors irons which are low in carbon and silicon. At high temperatures, deterioration is usually a form of oxidation in which the graphite is oxidized, dissolved carbon is graphitized, and finally the residual matrix is oxidized. Workers in this field agree that "growth" in oxidizing atmospheres which is the initial form of this deterioration, increases almost proportionally with an increasing silicon content. The graphitizing elements nickel and silicon would be expected to contribute to this effect, while the carbide-forming elements chromium, manganese, tungsten, molybdenum, vanadium and the like would retard the decomposition by resisting the expulsion of dissolved carbon. Since either silicon or nickel must be used to make a cast iron gray, a choice must be made between them. Sipp (Sipp and Roll, *Foundry Trade Jour.*, 1927, p. 114) reports that nickel does not increase growth. Other workers, notably Donaldson (J. W. Donaldson, *Foundry Trade Jour.* Feb., 1929), report to the contrary. Data obtained in the laboratories of the International Nickel Company (Bayonne, N. J.) show that if a plain and a nickel iron contain the same silicon content, the latter shows a slightly greater growth after repeated heatings in a muffle atmosphere. If the silicon is reduced, to compensate for the graphitizing power of the nickel, the growth decreases in proportion to the silicon reduction.

Among the carbide-forming elements, chromium seems to possess the greatest resistance to oxidation, and is most used. Its powerful tendency to cause chill spots and prevent machinability, limits its quantity to 0.30 per cent or less, but this amount can be doubled frequently if the chromium is accom-

panied by nickel additions which preserve the dense, gray structure, disperse the chill, and restore machinability.

NICKEL and chromium, and to a lesser extent, molybdenum, are added to cast iron to improve resistance to wear which is encountered in equipment engaged in sizing, screening, conveying, crushing, squeezing, macerating and pumping abrasive or tough material, frequently itself corrosive or floated in a corrosive medium. A nickel or nickel-chromium addition ranging from ½ to 4 per cent, made to a proper base mixture, progressively hardens and toughens the pearlitic matrix of plain cast iron without destroying the machinability. In some cases, an all-nickel addition is desired; in others, a 1 per cent nickel–0.30 per cent to 0.50 per cent chromium for mildly severe service or a 3 per cent nickel–0.75 to 1.0 per cent chromium content for extremely severe service. Centrifugal-pump castings, containing 3 per cent nickel with 0.75 to 1 per cent chromium and handling hot caustic, have been reported to be a marked improvement over plain cast-iron pumps.

Since erosion and corrosion are both active in this service, it is difficult to determine which condition is being most effectively resisted.

NICKEL alone or nickel and chromium constitute the principal alloying elements employed to improve pressure castings such as compressors, cylinder liners, autoclaves, valves or pipe-shaped castings. An excessive silicon content employed to secure the necessary machinability will in most instances be found responsible for leaky, porous, or poor pressure-resisting castings. This condition can usually be corrected by reducing the silicon content through the use of more steel scrap in the cupola charge, and a compensating addition of about 0.50 per cent nickel, for each 10 per cent of steel added, to retain the usual machinability.

NICKEL, with silicon and manganese as accessories, all properly balanced, are the principal alloying elements used in the production of high-strength cast iron.

Pumps, crushers, gears, driving mechanisms, journals, rolls, etc., where high stresses or high speeds are encountered or weights must be kept low, are being produced in high-strength nickel-alloyed cast iron. Usually 1.75 to 2.25 per cent nickel is employed, together with special precautions in the charging and operation of the foundry cupola. In addition to high strength, good machinability and excellent resistance to wear are developed.

INHIBITORS *as a Means of Reducing Corrosion*

By E. L. Chappell
Chemical Engineer, National Tube Company
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DURING the last two years considerable commercial interest in inhibitors for acid solutions has developed, and a number of new materials of this nature have been offered for sale. Inhibitors are essentially chemicals which, when added to an acid solution, prevent or diminish acid attack upon metals. They do not in general greatly affect the action of the acid on oxides or salts.

One reason for increased interest in inhibitors is the prevalent desire for industrial efficiency and avoidance of waste. Another is the more ready availability of satisfactory inhibitors. There is finally the development of a number of new commercial uses for acid solutions containing inhibitors.

The original and principal use of inhibitors is in pickling tanks where scale is removed from metal products. Recently acid which has been made inert toward metal has been used for removing various accumulations under other conditions. For example, it has been found practical to remove rust accumulations from clogged water lines by a rust solvent consisting of commercial muriatic acid plus an inhibitor. (Refer to Trans. Am. Inst. Chem. Eng., Vol. 19, 1927, p. 165, "Removal of Rust from Pipe Systems by an Acid Solvent," F. N. Speller, E. L. Chappell and R. P. Russell; also *Chem. & Met.*, July, 1927.)

Similar solutions are rapidly coming into use for the cleaning of barrels, tanks and other containers. This technique is useful also for the removal of scale accumulations from the water jackets and even radiators of internal combustion engines. The manner in which inhibitors make the above operations possible may be judged from the following summary of inhibitor action.

Inhibitors have the primary function of preventing the action of acid on metal. The effect is possibly due to the inhibitor substance being deposited or "plating" on the bare metal surface along with hydrogen and then remaining as a protective layer, invisible but effective. (See "The Electrochemical Action of Inhibitors in the Acid Solution of Steel and Iron," E. L. Chappell, B. E. Rotheli, and B. Y. McCarthy, *Ind. & Eng. Chem.*, June, 1928.)

The relative rate of removal of scale and of metal in the absence of an inhibitor depends considerably upon the acid concentration and upon the nature of the acid used. ("Acids Used in Galvanizing Work," Heinz Bablik, *Iron Age*, March 28, 1929.) The temperature of the bath also is of great importance. With the above factors fairly well fixed by practice, the relative commercial merits of inhibitors may be judged from the cost of the quantities required to accomplish equivalent protection of metal from acid attack.

Since metal solution is accompanied by equivalent hydrogen evolution, a convenient comparison of inhibitors is to determine the rate of hydrogen evolution from a standard metal under definite conditions. Several dozen commercial inhibitors have been given a routine test of this nature. Many of these newer materials are more effective than any described in a paper on the then available inhibitors published two years ago. (This paper may be found in Trans. Am. Inst. Chem. Eng., Vol. 19, 1927, p. 153, "Inhibitors—Their Behavior in Laboratory and Plant," F. N. Speller, and E. L. Chappell; also *Chem. & Met.*, July, 1927, p. 421.)

The routine test mentioned has been to place ½-in. lengths of ½-in. bessemer steel pipe in 300 cc. of 4 per cent H_2SO_4 at 160 deg. F. for 45 min., measuring the hydrogen evolved. Hydrogen evolution rates are expressed as cc. per square centimeter per hour. In the accompanying table are given the rates for a number of samples each of which appears to be representative of a general class of commercial inhibitors.

Comparative Tests of Inhibitors

Case	Inhibitor Conc., Per Cent	Hydrogen Evolution, cc./sq. cm./hr.	Inhibitor Cost, c./lb.	Efficiency Index, (Per Cent) x (Cost) x (Hydrogen Evolution)
A	None	30.	..	...
B	0.2	4.0	2	1.6
C	0.1	2.0	32	6.4
D	0.1	1.5	8	1.2
E	0.03	0.32	..	...

In the last column of the table is given an efficiency index which should be low for a good inhibitor. This index takes into account both inhibitor cost and effectiveness in saving metal or acid, since the purpose of using of inhibitor in plant pickling usually is either to save metal or to save acid. In addition, a good inhibitor must not, of course, have injurious effects either on material or workmen. Some experimentation before putting it into plant use accordingly is desirable. The cleaner and smoother surface of materials pickled using inhibitors is an important consideration.

Early Obsolescence May Dictate Common

IRON AND STEEL

By E. L. Chappell
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FOR THE PURPOSE of the present discussion, plain iron and steel may be taken to include those ferrous materials which may be readily obtained in carload lots from a number of makers in the form of castings, pipe, plates, or bars, at the current competitive price of 1 to 6c. per pound. Although rapid progress has been made in the development of alloyed steels and of non-ferrous materials for use in the chemical industries as materials of construction it remains, however, that cast iron and carbon steels are the materials from which most equipment is constructed. Cast iron and steel are available in almost any desired form.

Cast iron is available as special castings and as pipe at the lowest cost per pound of any metallic material. Because of this it may be cheaply used in thick sections which are desirable where corrosion proceeds at a definite but moderate rate. Another advantage is the possibility of readily casting it in almost any desired shape or quantity, so that once patterns are available, replacement is cheap and easy.

Steel is available in the form of plates, sheets, tubes, bars, wire and so on. Ordinary variations in chemical composition, with the exception of the copper content, do not greatly affect its corrosion resistance. Its cheapness, strength, ready availability, ease of working and freedom from the unpredictable aging effects which may occur in less uniform and stable materials are of unique advantage. The development of oxyacetylene cutting and welding equipment has greatly facilitated the fabrication of steel apparatus in special forms.

Cast iron and steel used in the chemical industry may be exposed to several forms of corrosion which can be roughly divided, according to the chemical processes involved and the corrosion products formed, into the following groups:

A—Water and Oxygen
B—High Temperature and Oxygen
C—Chemical
  1—Organic Materials
  2—Acids
  3—Alkalis
  4—Salts

In any one of the above groups, with the exception of certain cases, special materials can be obtained at higher prices which will exceed in permanence plain cast iron or steel. Whether it be economical to use the more resistant materials, however, is a problem of economic balance between initial cost and replacement cost which can best be settled by experience. The corrosion groups may be summarized separately as follows:

Water-and-Oxygen Corrosion—This, the most common form of corrosion, may be described as ordinary rusting, since it usually results in a deposit of hydrated ferric and ferrous oxides. It always tends to occur when ferrous materials are exposed to air and water, but its rate is influenced by a large number of external factors such as temperature, velocity, etc.

In many cases this natural corrosion rate does not cause failure before the end of the useful life of the equipment due to obsolescence; so that by far the greater part of structural work, water tanks, and water piping is made of ferrous material. Even where corrosion is expected to be severe, economy may still indicate that no protective means will pay for itself and corrosion should be allowed to proceed. However, in other cases, as for example water tanks, protective coverings are common practice, tending toward the use of thick organic coatings. Pipe may be protected by linings of cement or asphalt.

In considering resistance to water-and-oxygen corrosion, two somewhat special products which still come under the definition of plain iron and steel first given, may be mentioned. The first is steel containing 0.25 per cent copper, which is supplied by most steel makers in customary forms at an advance of only 3 to 6 per cent over ordinary materials. This small amount of copper in steel has been found to increase its life by several times when exposed to the atmosphere. The other common product readily available, which should be mentioned in this connection, is galvanized steel, which is at its best when used for resistance to alternate wet and dry atmospheric corrosion. It is also found that water plus oxygen at moderate temperatures, particularly in the presence of certain scale-forming salts, attacks galvanizing very slowly. Recently noted successful uses of galvanizing are on the sea-water side of ammonia condensers and on the benzol side of benzol-still condenser tubes.

High-Temperature and Oxygen Corrosion—High temperatures plus oxygen oxidize iron and steel with the formation of a blue-black layer of mixed oxides, the rate of reaction depending, of course, on the temperature. The practical limit of temperature to which cast iron or steel is used may be determined either by the rate of this oxidation or by loss of physical strength. Cast iron is used for low pressures up to 400 or 500 deg. F. or even higher. Where no pressure is involved, cast iron is used up to a red heat in the form of dampers, grate bars, and other parts. The thick section of cast iron and also its chemical content are of advantage since high temperature oxidation is a fairly slow but steady process.

Steel is the material commonly used for fairly high pressures up to 300 or 400 deg. F. and for moderate pressures up to 700 or 800 deg. F. Above 1,000 or 1,200 deg. F. the rate of oxidation of plain steel becomes serious and its strength is reduced so that substitute materials or special treatments are generally advisable.

Chemical Corrosion—Chemical corrosion may be taken to include attacks by organic materials, acids, alkalis and various salts.

Organic materials, unless containing active acid radicals, do not seriously corrode ferrous materials, so that their use is standard for much large-scale organic equipment. In some cases the use of cast iron or steel is impracticable, even in the absence of serious corrosion, since small quantities of colored corrosion products may be objectionable.

Most dilute acids, especially when warm, form soluble iron salts, and corrosion proceeds at a uniform and frequently a rapid rate. On the other hand, high concentrations of sulphuric acid are, of course, readily handled in iron or steel, due apparently to the formation of insoluble corrosion products. Although some corrosion occurs, it at times proves economical to use cast iron or steel with rather dilute acids. In this connection, the copper steel mentioned above may be suggested as exhibiting considerably increased resistance to dilute acid corrosion.

Alkalis, except when very hot and concentrated, are satisfactorily handled in cast iron or steel. Care to avoid excessive strains of cast iron when used with strong alkalis is advisable.

Salts, especially when fused, cover a wide range of properties and no detailed discussion will be attempted. Each case must be settled by experiment.

Solutions of salts in water generally

present special cases of oxygen-and-water corrosion which has already been discussed. The first effect of the salt is to decrease the solubility of oxygen, decreasing corrosion as with chloride brines. However, effects upon the accumulation of corrosion products may more than offset this. In some cases, as with chromate, corrosion is prevented in salt solutions.

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Where HIGH-SILICON IRONS *Serve Chemical Industry*

MANY ARTICLES on the subject of high-silicon alloys and their applications to the chemical and allied industries have been published during the last few years, and the question of value and limitations of these materials is becoming very generally understood. There still exists, however, some misunderstanding as to the inherent characteristics and proper applications of these alloys.

In speaking generally of these high-silicon irons, it is necessary to bring out the point that the term "high-silicon irons" is indefinite and likely to be misleading. The corrosion resistance of such alloys diminishes very rapidly with decreasing silicon content or increasing carbon content. A standard composition of such irons should be approximately as follows:

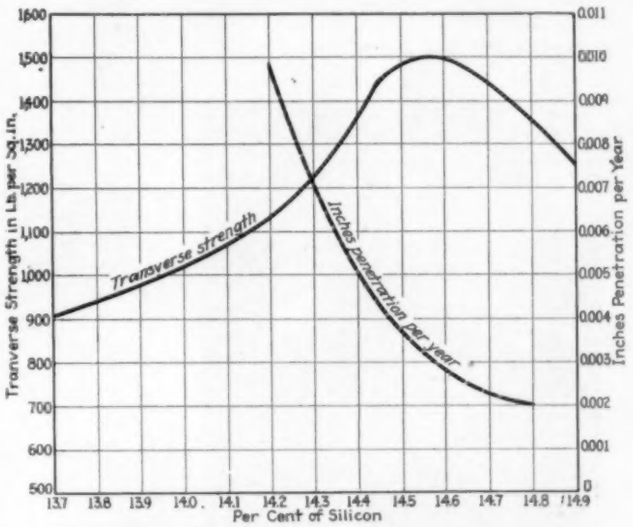
Silicon	14.25-14.50 per cent
Carbon	0.75- 0.85 per cent
Manganese	0.30- 0.60 per cent

The addition of small amounts of nickel, chromium or other carbide-forming elements is permissible and has a tendency toward increasing both the transverse strength and the impact resistance.

In the graph is illustrated very clearly the rapidly decreasing resistance of these alloys to corrosion with decreasing silicon content. In the samples from which this curve was plotted the carbon content was maintained slightly below the saturation point. A lower carbon content is likely to increase the brittleness of the alloy while, if the carbon exceeds the saturation point, it will be present in the castings in the form of segregated pockets of graphite.

The question is frequently raised of a higher silicon content in this class of alloys. It is true, as the graph indicates, that with increased silicon content, up to at least 18 or 19 per cent, the resistance to most of the mineral acids is increased. One of the limitations to a more general usefulness of the high-silicon irons, however, is the comparatively low tensile strength and susceptibility to impact. Contrary to previous theory, the strength does not decrease directly with the increase in silicon. The greatest transverse strength of high-silicon alloys in the range between 11 and 20 per cent silicon occurs at approximately 14.50 per cent. The graph illustrates the relation between transverse strength and silicon content. Tests extending over a period of years indicate that high-silicon irons of the composition given above are the most practical product, being, in fact, a compromise to obtain maximum acid-resisting properties combined with maximum physical strength.

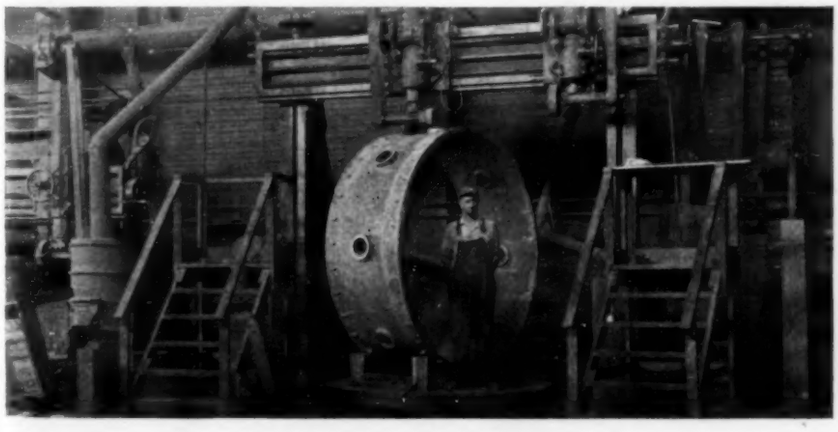
These alloys are particularly valuable in their resistance to an extremely wide range of corrosive conditions, the range being such that they can almost be termed universal acid resistants. They stand practically alone in their ability to resist hot concentrated sulphuric acid, copper sulphate solutions, tin tetrachloride, and conditions where both nitric and sulphuric acids are present. While not usually considered suitable for hot concentrated hydrochloric solutions, high-silicon alloys withstand to a fairly satisfactory degree weak, hot solutions of hydrochloric acid and concentrated cold solutions, and probably are the best practical alloys for this type of work.



Curves Showing Influence of Silicon Content on Chemical Resistance and Transverse Strength of High-Silicon Iron Alloys

Probably the greatest single difficulty in the use of high-silicon alloys lies in equipment where more or less rapid changes in temperature are unavoidable. It is possible to minimize the danger of cracking by, as far as possible, sectionalizing the apparatus and providing ample facilities for expansion and contraction. Tower sections, for example, which formerly were made with a height possibly three or four times their diameter, are now designed in the larger sizes with a height not over half their diameter. Experience has proved that in a cylindrical section subject to appreciable temperature changes in no case should the height be greater than one and one-half times the diameter. For handling solutions which necessarily vary in temperature to a considerable degree, high-silicon pumps and valves should

Finishing a Duriron Tower Section; Note Proportions of the Section



not be used unless the rate of temperature change can be slowed down approximately to a rate of 100 deg. F. per minute.

The application of high-silicon irons has been considerably broadened by the developments in welding which have become an important part of manufacturing operations. Coils, jets, return bends, condensers and other similar equipment are now regularly produced by butt welding lengths of cast pipe.

Modern high-silicon iron, while improved in many respects, is still practically unmachineable. Limited turning operations can be performed with tungsten carbide tools, but as yet, grinding is the standard and most economical method of machining.

In spite of the admitted drawbacks to high-silicon irons, they have been, and are continuing to be, an extremely valuable addition to the materials of construction for the chemical industry. Not only have the alloy itself and the equipment constructed therefrom been improved but the larger users of such

Duriron Column Assembled Ready for Test Prior to Shipment

equipment have become so familiar with its characteristics and the proper methods of installation that failures in service are unusual. It is unfortunate, perhaps, that so much was expected of these alloys. Because of the general similarity in nomenclature and appearance, many users have assumed that high-silicon irons could be handled in the same manner as cast iron. As a better understanding of the value and limitations of these irons becomes general, the high-silicon alloys are rapidly taking their place with other standard materials of construction in assisting the chemical industry to the solution of many perplexing corrosion problems.

New Alloys Withstand HYDROCHLORIC ACID

By Burnham E. Field

Union Carbide & Carbon Research Laboratories, Inc., Long Island City, N. Y.

DEMAND for special alloys, to meet special requirements in the handling of acids and other corrosive chemicals, is constantly increasing. Three new alloys have been developed by the Union Carbide & Carbon Research Laboratories, which it is hoped will help to satisfy this demand. They are being made and sold by the Haynes Stellite Company, Kokomo, Ind., under the trade name "Hastelloy" with letter designations of grade.

Hastelloy A—Hastelloy A is a nickel-molybdenum-iron alloy of high strength and good ductility which is particularly resistant to hydrochloric acid. This alloy makes excellent castings, can be forged, rolled into sheet and welded by either the oxyacetylene or arc method and is readily machinable. It is not yet available in the form of seamless tubing, but it is hoped that this will be a later development. Hastelloy A is resistant to most acids except nitric, hot and cold. In 37 per cent HCl at room temperature it shows a loss as little as 0.000001 g. per square centimeter per hour, or 0.00003 in. penetration per month. In 10 to 37 per cent HCl at 70 deg. C., this loss will vary from 0.00005 to 0.00008 g. per square centimeter per hour, the stronger acid being the less corrosive. This corresponds to a penetration of about 0.002 in. per month. In sulphuric acid the loss is slightly less than in hydrochloric. Table I gives the most important physical properties of the alloy.

Hastelloy C—By a modification of the composition of Hastelloy A, resistance to strong oxidizing agents such as nitric acid, wet chlorine and acid solutions of ferric salts, cupric salts and so on, is secured, but at the expense of the workability of the alloy, so that it must be used in the cast form. This modified alloy is known as Hastelloy C. It is machineable, is more resistant to sulphuric acid than Hastelloy A, and is practically as resistant to hydrochloric acid.

Hastelloy D—The third alloy also is a nickel-base casting alloy of somewhat different type. It contains an appreciable quantity of silicon and small amounts of aluminum and copper. This alloy may be compared with the iron-silicon acid-resistant alloys, with the important exception that it is strong and tough. It is particularly resistant to sulphuric acid and at the same time is quite resistant to hydrochloric acid. It makes excellent castings but it is not machinable except with tungsten-carbide tools or by grinding. Although Hastelloy D has a rather complex microstructure, it welds without difficulty with the oxyacetylene torch. Table II gives the important physical properties of the alloy.

Table I—Physical Properties of Hastelloy A

Specific gravity, forged	8.8
Weight per cu.in., lb.	0.315
Weight per cu.ft., lb.	514
Melting point	1,300 deg. C.
Coefficient of expansion, in. per deg. C.	10.7×10^{-6}
Thermal conductivity per deg. C., cal. per sq.cm. per cm. per sec	0.004
Electrical resistivity, microhms per cm. cube at 24 deg. C	126.7
Electrical conductivity, per cent of copper at 24 deg. C. (75 deg. F.)	1.4
Shrinkage, sand castings, in. per ft.	$\frac{1}{4}$
Forgings: Yield point, lb. per sq.in.	51,700-69,100
Ultimate strength, lb. per sq.in.	112,600-117,300
Elongation in 2 in., per cent	33.5-24.1
Reduction in 2 in., per cent	37.9-31.2
Brinell hardness, average	207
Rockwell B. hardness, average	97
Erichsen test: Hot-rolled sheet	5.0
Annealed sheet	8.0

Table II—Physical Properties of Hastelloy D

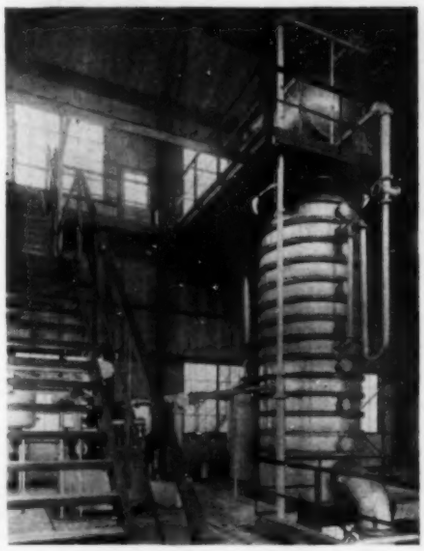
Specific gravity	7.8
Weight per cu.in., lb	0.280
Weight per cu.ft., lb	484
Melting point	1,160 deg. C.
Coefficient of expansion, in. per deg. C.	116×10^{-6}
Thermal conductivity per deg. C., cal. per sq.cm. per cm. per sec	0.005
Electrical resistivity, microhms per cm. cube at 24 deg. C	112.0
Temperature-resistance coefficient per deg. C.	0.0013
Electrical conductivity, per cent of copper at 24 deg. C.	1.6
Shrinkage, sand casting, in. per ft.	$\frac{1}{4}$
Transverse breaking load, 12 in. span., lb.	5,000
Deflection, in.	0.070-0.080
Modulus of rupture	78,200
Brinell hardness	364

Varied Application Characterizes

ALUMINUM

In Industry

By Paul V. Faragher
Aluminum Company of America, New Kensington, Pa.



IN CHOOSING a material to be used in the construction of chemical equipment, consideration must be given not only to the corrosion-resisting qualities of the material but to its mechanical characteristics as well. There is no material of construction which will resist all forms of corrosion. One or more materials, however, are particularly adapted to each individual type of corrosion. Wherever aluminum may be used, it presents a valuable combination of mechanical properties which makes it an important material of construction in the chemical field. The metal may be worked and cast with comparative ease. It is light in weight (specific gravity, 2.70), while most of the other metals used in the construction of chemical equipment are from 2.5 to 3.25 times as heavy as aluminum.

Commercial purity in the case of aluminum is based on a minimum content of 99 per cent. The chief impurities are copper, iron, and silicon. By a special refining process, it is possible to produce aluminum of very high purity. In general, however, the commercial grade of aluminum is employed in the chemical industry.

Not infrequently, considerations of mechanical strength make the use of an alloy desirable. Moreover, more intricate castings can be obtained in the alloys than in commercially pure aluminum. The addition of the commonly used alloying elements to commercial aluminum, however, with a single exception, decreases the resistance of the metal to corrosion.

This exception is manganese. In the manufacture of wrought products such as sheet, rod, and tubing, an alloy containing 1.25 per cent manganese is extensively used. This alloy, known as 3S, may be safely substituted for the pure metal in many of its applications.

For the production of castings to be used in chemical equipment, the alloys of aluminum with silicon show the best results. In addition to their superior corrosion resistance, as compared with the more commonly used casting alloys containing copper or zinc, they have excellent casting characteristics. This makes possible the production of sound, leakproof castings.

Many of the failures of aluminum have been traced to the use of low-grade metal, or to the use of an alloy which was not adapted to the requirements of the chemical industry. The presence of small amounts of foreign substances in the chemicals may also alter their normal behavior toward the metal. These effects may be either harmful or beneficial, as may best be shown by specific illustrations.

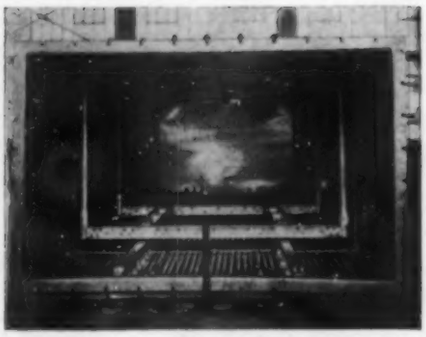
It is well known that aluminum is quite readily attacked by alkaline substances. It has been found, however, that the presence of a very small percentage of sodium silicate inhibits this action. Advantage is taken of this fact in the manufacture of cleansers and washing powders for use in contact with aluminum.

Aluminum is unaffected by contact with pure water. Experience has shown that it is entirely satisfactory for storing and piping distilled water for use in analytical laboratories. However, some natural waters contain sufficient concentrations of salts to cause serious corrosion of aluminum after a period of time. It has been found that many of these waters can be rendered harmless by adding a small amount of potassium or sodium dichromate.

A dense alundum thimble packed with the dichromate and carefully stoppered, suspended in the intake line, will permit sufficient leaching of the salt to protect aluminum equipment with which the water comes in contact. The actual concentration of dichromate in the water is very low, since such a thimble requires refilling only at intervals of several months. In the case of a closed system where the water is continuously recirculated, the soluble dichromate may be added in a concentration equal to about 0.1 per cent of the total concentration of chloride, bicarbonate, and borate. Aluminum condensers and heat exchangers are being operated successfully with water treated in this manner, in regions where the raw water would have caused serious trouble.

As an example of the opposite effect, the experience with nitric acid may be cited. Aluminum apparatus is standard for use in the handling of nitric acid made from atmospheric nitrogen. Storage tanks, pipe lines, and shipping

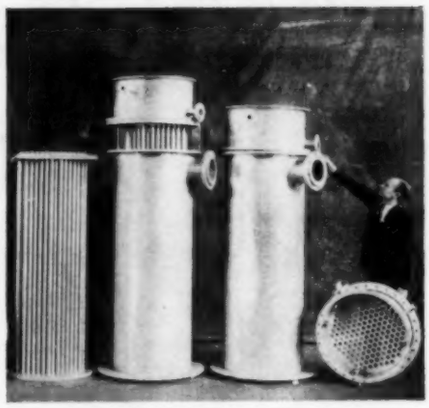
Riveted Aluminum Tank Car for Shipment of Glacial Acetic Acid



Interior of Retort for Turpentine Distillation From Yellow Pine Lumber; Construction Is Entirely Aluminum

drums give excellent service when made from aluminum and only superficial attack is experienced from either the acid or its vapors. If, however, acid made from Chile saltpeter is handled in aluminum, serious corrosion may result. This action has been variously attributed to the presence of chlorides, or of iodine compounds arising from the salt from which the acid was made. Small concentrations of sulphuric acid in the nitric acid may account for the action which occurs. It has also been stated that the presence of certain of the oxides of nitrogen, dissolved in the acid, may materially increase its action on aluminum.

Electrolytic corrosion may result from the contact of aluminum with a metal which stands higher in the electromotive series. In so far as possible, dissimilar metals should not be simultaneously in contact with each other, and with materials which are even mildly corrosive. Where it is not possible to avoid the use of heavy metals in contact with aluminum, electrical contact should be at least avoided by the use of suitable



Tubular Condenser Parts, All of Aluminum; Tubes Are Expanded Into Headers

gaskets, insulating paints, or cements. In case the heavy metal is subject to attack by the chemicals which are being

Action of Various Chemicals on Aluminum Equipment

Acetic Acid—Aluminum equipment is used in handling acetic acid in a wide range of concentrations and at temperatures up to the boiling point. The rate of attack increases to a maximum at about 1 per cent acid, the rate in boiling acid being about four times that at ordinary temperatures. As the acid concentration is increased, the rate of attack decreases abruptly till at 5 per cent it has fallen off to about one-third the maximum value in the cold acid and to about one half, in the case of boiling acid. As the concentration is further increased, the action gradually decreases until at 99.5 per cent it is practically negligible.

Where pure acid can be formed either from the use of efficient dephlegmating apparatus or by the addition of the acid anhydride, it is reported that the attack may be serious. A few tenths of a per cent of water is sufficient, however, to practically inhibit this action. On the other hand, Calcott and Whetzel describe tests made with boiling 100 per cent acid in which they found a very low rate of attack. They found, however, that a small addition of the anhydride did materially accelerate the action. While the corrosion of aluminum in hot acid at concentrations below about 90 per cent is not very rapid, it probably is too great to warrant the use of the metal except where such use is demanded by special consideration.

At all temperatures and concentrations, the presence of certain impurities such as chlorides, heavy metal salts, formic acid and perhaps certain others, may adversely affect the nature of the attack. The presence of a small percentage of sulphuric or of nitric acid will retard or even prevent local attack.

The higher homologues, propionic and butyric acids, and so on, behave similarly to acetic acid, but because of the greater ease of obtaining these acids free from water, somewhat greater care is required to avoid the action of the pure acid.

Acetic Anhydride — Aluminum containers are recommended for storing and shipping acetic anhydride. Mixtures of acetic acid with the anhydride, particularly those containing more than 10 per cent of the acid, should not be handled in aluminum.

Acetone — The storage of redistilled acetone in aluminum has been reported to have caused a slight local attack which may have resulted from impurities in the fermentation of starch to produce acetone and butyl alcohol.

Alcohols—There is some disagreement as to the suitability of aluminum for use with alcohols. One investigator reports that the lower alcohols: i.e., methyl, ethyl, propyl, butyl and amyl, may be handled in aluminum provided they are free from traces of acids or alkalis. Seligman and Williams state that the alcohols, if sufficiently anhydrous, attack aluminum at elevated temperatures. A large manufacturer of solvents, including the higher alcohols, who uses aluminum extensively in his culture tanks, has experienced no difficulty from corrosion. Another user reports that aluminum distilling apparatus is entirely satisfactory for alcohol.

Alkalis—All caustic alkalis attack aluminum vigorously. Substances, which in aqueous solution hydrolyze to give a mildly alkaline reaction, corrode the metal more slowly in proportion to the degree of alkalinity; e.g., soaps, alkali metal carbonates, phosphates, borates, etc. By the addition of small concentrations of sodium silicate or potassium dichromate, this action may be inhibited or at least greatly retarded. Aluminum is best adapted for use in contact with solutions having a pH value of from 6.4 to 7.2.

Alum and Aluminum Sulphate—Aluminum cooling trays are used in the preparation of these substances. The metal is not entirely immune to attack, but is reported to give satisfactory service. The use of aluminum equipment has the advantage of preventing contamination from heavy metal salts which is objectionable for many uses.

Ammonia and Ammonium Hydroxide—Gaseous ammonia does not attack aluminum. Ammonium hydroxide attacks the metal superficially with the formation of a protective coating which effectively prevents further action, provided the solution is free from alkali metal salts. Aluminum is extensively used in ammonia recovery equipment in coal-gas plants. It also is used in refrigerating systems with ammonia as the refrigerant.

Ammonium Bicarbonate, Carbamate, Carbonate—Aluminum equipment is satisfactorily used for the production of these compounds. It is especially suited for the subliming apparatus because of its good thermal conductivity, and because the product is not contaminated with heavy metal salts.

Ammonium Nitrate — Aluminum equipment is used in the neutralizing of nitric acid with ammonia, in concentrating the liquors and crystallizing the salt. In addition to its satisfactory behavior from the standpoint of corrosion, aluminum has the advantage of not introducing unstable metal compounds which might initiate explosions in the ammonium nitrate. The fact the aluminum does not form sparks when struck or abraded is an advantage when mixing the nitrate to form explosive mixtures.

Ammonium sulphate is made in aluminum equipment by neutralizing ammonia with sulphuric acid (see Alum).

Aniline and other amino hydrocarbons attack aluminum at temperatures near the boiling point, replacing one or both of the hydrogen atoms in the amino group. Satisfactory results are obtained, however, by using aluminum acetylators in making acetanilide.

Benzoic acid may be sublimed in aluminum apparatus.

Benzol—The purification of benzol in aluminum distillation and dephlegmating equipment may be carried out successfully since the metal is not attacked by sulphur compounds which are commonly present as impurities. Benzol is without action on aluminum.

Boric Acid—The rate of attack with this acid is slow and is dependent upon the concentration of the acid.

Bromine attacks aluminum vigorously.

Borax—See Alkalis.

Butyric Acid—Similar to acetic acid q.v.

Calcium chloride solutions, in common with other chlorides, tend to cause corrosion of aluminum, the attack usually being more severe at the water line. However, the action varies considerably with the specific conditions of use. One manufacturer, using aluminum condensing coils immersed in a calcium chloride brine which is acid with acetic acid, reports excellent service from the installation. The presence of chlorides as an impurity in other materials is frequently responsible for the failure of aluminum equipment. As has been previously stated, small concentrations of alkali metal chromates or dichromates may entirely inhibit the corrosive action of waters containing chlorides.

Carbon disulphide does not attack aluminum.

Carbon Dioxide, Carbonic Acid—The gas does not attack aluminum. Carbonated waters are also handled successfully in aluminum equipment although there may be some attack.

Carbon tetrachloride in the presence of water hydrolyzes slightly to form hydrochloric acid, which has a corrosive action on aluminum; this action is more severe at elevated temperatures. In spite of this fact, aluminum tubing has been used in the manufacture of fire extinguishers containing this substance, and the results have been reported to be satisfactory. (See Ethylene Dichloride.)

Chlorine—It has been reported that the perfectly dry gas does not attack aluminum at ordinary temperatures. Under ordinary conditions, however, the attack is vigorous.

Citric Acid—Aluminum is extensively used in the commercial preparation of citric acid because of the fact that any slight contamination with aluminum salts is not objectionable in the use of the acid in beverages. For the same reason, aluminum equipment is used in the preparation of effervescent saline preparations such as citrate of magnesia.

Cresols—See Phenols.

Edible Oils and Fats—Aluminum is not appreciably attacked by the acids which may be present. Aluminum equipment is used in the preparation, storage, transportation, deodorizing and purification of edible oils and their products. Any slight contamination with aluminum salts is not objectionable in food products.

Ethyl Acetate — Aluminum is satisfactory for handling ethyl acetate provided it is practically free from water, even though it may contain traces of acetic and sulphuric acids.

Ethylene dichloride does not hydrolyze with water, and hence may be used with aluminum.

Fatty acids such as olive, palmitic, and stearic do not attack aluminum up to a temperature of 300 deg. C. (572 deg. F.), according to Seligman and Williams, provided a small amount of water is present. If water is absent—and oxygen is excluded so none can be formed by reaction with the acids—the reaction temperature is said to be lower. Butyric and propionic acids are said to behave in a similar manner.

Formaldehyde, when pure, does not attack the aluminum equipment which is extensively used in the distillation, storage and shipment of this substance. The presence of benzaldehyde, or of formic acid, may cause serious attack.

Formic acid attacks aluminum vigorously, and even when present as an impurity in other products such as acetic acid or formaldehyde, may cause serious corrosion of aluminum.

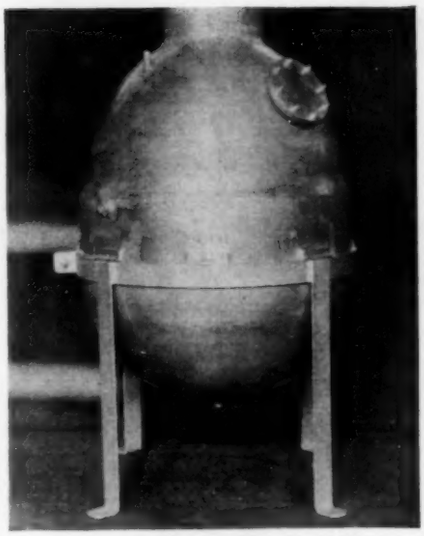
Fruit Acids—Because of the fact that aluminum compounds are entirely harmless, even when present in foods in far greater concentrations than are ever reached from the use of aluminum cooking equipment, such equipment is extensively used in the preserving and bottling industries. Any action of the fruit juices is superficial, and does not harm the metal nor the food product. Some few of the fruit products which are prepared in aluminum on a large scale are cranberry jelly, grape juice, pineapple preserves, orange marmalade, etc. It is interesting that some trouble which was reported with corrosion of aluminum by fresh pineapples was entirely overcome by the addition of the sugar to the fruit before it was cooked in the aluminum kettles.

Gasoline—When properly refined and neutral, gasoline has no effect on aluminum. But if the alkali used to neutralize the acid in the refining process is not properly washed out, the alkali will, of course, cause corrosion.

handled, even this precaution is not sufficient. Aluminum will replace the heavy metal salts in the solution, plating the metal on its surface, thus establishing local couples which may further accelerate corrosive action.

Temperature also exerts an effect on the rate of chemical reactions, which is too often lost sight of when reporting corrosion data. Aluminum may be entirely satisfactory for the storage and shipment of a chemical, and at the same time not be suited for a still or condenser to be used in its purification.

The accumulation of products of corrosion on the surface of the metal may induce local attack or pitting, with the ultimate perforation of the wall long before there is any appreciable loss of metal due to the uniform action of the reagent. Such action may be avoided, and the life of the equipment greatly prolonged, by proper cleaning.



Aluminum Jacketed Digester, All-Welded Construction

The method of measuring the effects of corrosion may also affect the interpretation of experimental data. When there is a tendency toward local attack, measurement of the loss of weight over a period of time may be entirely misleading, since a single pit may be sufficient to destroy the usefulness of the metal, even though the attack over the surface may be negligible. For many purposes the loss in mechanical properties, as a result of the chemical action, is a valuable indication of the suitability of a metal. In general, however, actual trial under conditions of service is the only test which can be depended upon to give a satisfactory answer.

The information given in the tabulation concerning the use of aluminum with various chemical substances has been taken from the literature on the subject of corrosion, and in many cases is substantiated by experience.

Action of Various Chemicals on Aluminum Equipment

Gelatine and Glue—Aluminum is used extensively in the various processes for the manufacture of gelatine and of glue. Because of the restrictions of the pure food laws, aluminum is one of the few metals which can be used for edible gelatine.

Glycerol—Without action except as it may be contaminated with harmful impurities.

Gums—See Varnishes.

Hydrochloric Acid—Aluminum is unsatisfactory for use with hydrochloric acid.

Hydrogen sulphide does not corrode aluminum, even at high temperatures in the presence of steam.

Iodine attacks aluminum, although less actively than the other halogens.

Lactic acid, when pure, behaves toward aluminum very much like acetic acid. The presence of chloride increases the action, while certain organic substances which are present in milk practically inhibit corrosion. Even sour milk used in the manufacture of cheese does not harm the metal. Aluminum is extensively used in the dairy industries abroad and this use is coming into increasing favor in this country.

Milk, Milk Sugar (Lactose), etc.—See **Lactic Acid.**

Mercury and Mercury Salts—Aluminum is not readily wetted by mercury, but once the amalgamation is started it proceeds rapidly with the destruction of the metal. The alloy containing manganese (38) appears to be even more resistant to metallic mercury than is pure aluminum. Solutions of mercury salts attack the metal fairly readily, although abrasion of the surface increases the action. If the surface of aluminum is amalgamated, it reacts readily with the moisture of the air to form a dense, moss-like growth of aluminum hydroxide. The action continues until the metal is destroyed.

Naphthols—See Phenols.

Naphthylamine—See Aniline.

Nitric Acid — Aluminum has found a considerable application in the manufacture and the handling of nitric acid. The metal has been used in equipment for storing, piping and shipping the acid, as well as for the enormous pipe lines used in the process for manufacturing the acid from atmospheric nitrogen. It has already been pointed out that there are certain limitations to the use of aluminum for this purpose. (See introduction, above.)

The general rule that, on the average, a rise in temperature of 10 deg. C. (18 deg. F.) doubles the rate of a chemical reaction, applies very well to the reaction between aluminum and nitric acid. The concentration of the acid also is of great importance. Concentrated acid containing in excess of 90 per cent HNO_3 made from atmospheric nitrogen is practically without effect on the metal. Aluminum shipping drums are well suited for use with such acid.

The most rapid attack occurs in solutions containing between 20 and 40 per cent by volume of acid having a density of 1.42. The reaction rate decreases as the concentration increases or decreases from this range. Several users have reported satisfactory results from aluminum equipment with nitric acid in the higher concentrations at ordinary temperatures, some having specifically stated that no trouble is experienced if the acid content is not less than 50 per cent. Aluminum is used with very dilute solutions even at higher temperatures.

As was stated previously, small amounts of certain impurities may be sufficient to render the acid unfit to be handled in aluminum equipment. Sulphuric acid, lower oxides of nitrogen, and to a lesser extent traces of chlorides, may be mentioned in this list. It has also been suggested that iodine or some of its compounds may be present in acid made from Chile saltpeter and may contribute to the action which is sometimes observed with aluminum.

Nitrous gases can all be handled in aluminum, although certain of the lower oxides, when dissolved in nitric acid (q.v.) accelerate the rate of attack. Aluminum covers for nitrating tanks, fume hoods, and ventilating ducts are extensively used where nitrogen gases are to be handled.

Oxalic Acid—Laboratory results indicate that all concentrations of this acid cause slow uniform solution of aluminum, the rate being increased at elevated temperatures. It is interesting, however, that a large installation of aluminum equipment has been in use for a considerable length of time for the manufacture of oxalic acid and no difficulties have been reported.

Paraldehyde—No attack.

Phenol—Phenols and cresols do not attack aluminum, even at elevated temperatures, provided they are not completely anhydrous. In the total absence of water, the reaction is quite vigorous at high temperatures. The successful use of aluminum stills for the distillation of tars doubtless is due to the fact that they are seldom anhydrous.

Phosphoric Acids — All of the acids in this group attack aluminum.

Picric Acid—The fused acid does not react with aluminum, but its solutions are rapidly reduced by the metal.

Potassium chlorate is dried in aluminum trays.

Propionic Acid—See Acetic Acid.

Resins—See Varnish.

Salicylates and salicylic acid are handled extensively in aluminum, and the results are satisfactory provided a proper grade of metal is used.

Soap — Soaps, shaving creams, vanishing creams, and similar preparations slowly corrode aluminum, but the addition of a small amount of sodium silicate completely inhibits this action. Aluminum is used extensively and successfully in washing machines. There is little tendency for corrosion to occur during the relatively short periods that the aluminum is in contact with the hot soap solutions. Moreover, the deposit of insoluble calcium and magnesium soaps formed from the impurities in the water tends to protect it.

Sodium Carbonate — The action of this salt varies from a slight discoloration by dilute solutions to vigorous attack with evolution of hydrogen by more concentrated solutions at elevated temperatures. The addition of a small amount of sodium silicate inhibits this action completely so that a mixture of these two compounds can be used for cleaning aluminum apparatus.

Sodium Chloride (See also Calcium Chloride)—Chlorides present a difficult problem from the standpoint of corrosion. There are certain installations of aluminum equipment in which the metal is giving satisfactory service in contact with brines. In general, there is corrosion over a period of time, but the service may be better than that obtained from other materials which might be used. The suitability of aluminum in contact with salt solutions can best be determined by trial under the proposed conditions of operation.

Sulphur does not attack aluminum except at very high temperatures. Aluminum equipment is used in obtaining sulphur from the material deposits in the earth. Molten sulphur or its vapors do not combine with the metal.

Sulphur Dioxide and Sulphurous Acid—Sulphur dioxide does not attack aluminum even at the elevated temperatures which prevail in flue gases, in vulcanizing chambers, or in petroleum refining stills. This fact is of great importance in those industries in which the problem of sulphur corrosition has been so serious. Aluminum is used for rubber molds, inner-tube mandrels in the rubber industry, for conduit for electric wiring and for flue-gas ducts in railway round houses. The use of the metal in the petroleum industry is assuming considerable proportions. Liquid sulphur dioxide, if dry, may also be handled in aluminum, which fact is receiving attention in the refrigeration industry. Aqueous solutions of the gas cause a slow, uniform attack of the metal.

Sulphuric Acid — Aluminum is not seriously affected by dilute solutions of sulphuric acid at ordinary temperatures. The rate of attack increases with increasing concentration and temperature. Calcott and Whetzel report a gradual increase in the rate of penetration up to 0.04 in. per month at ordinary temperatures (25 deg. C. = 77 deg. F.) as the concentration increases from 5 to 50 per cent. The acid is reduced to form hydrogen, sulphur dioxide, sulphur, or even hydrogen sulphide, depending upon the conditions of temperature and of concentration. The fuming acid has little or no action on aluminum in the cold, even at 120 deg. C. The only evidence of attack is the development of a brilliant silver-white protective coating.

Tannic acid corrodes aluminum.

Tartaric acid has some action on aluminum, but because of the extensive use of this acid in food products, aluminum equipment is used in order to avoid contamination with objectionable metal compounds. Very satisfactory results are reported for the life of such equipment. Racemic acid is stated to be without action on the metal, but there is attack with pyroracemic acid.

Toluidine—See Aniline.

Turpentine does not attack aluminum. Extensive installations for rectifying and condensing turpentine are in use also for the production of terpene acetyl derivatives.

Varnishes — The acids in the gums and resins and vegetable oils used in the manufacture of varnishes do not attack aluminum even at the relatively high temperatures used in processing some of these materials. The fact that aluminum salts are colorless is an advantage since varnishes are graded on the basis of color. Varnish kettles of aluminum are extensively and successfully used. Proper care must be used in designing such equipment since the metal is comparatively weak at the elevated temperatures required for some of the gums.

Water—Pure water does not attack aluminum. Aluminum may be used for condensing coils, storage tanks and pipe lines for distilled water, even for use in analytical laboratories.

Natural waters may or may not corrode the metal, depending upon the nature and concentration of the impurities. The inhibiting action of small additions of soluble dichromates has already been mentioned. It is not possible to define the conditions which will cause trouble in service; trial installations can alone be relied upon to give positive information.

NICKEL AND NICKEL ALLOYS

Offer Diverse Corrosion Resistance

By R. J. McKay

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RESISTANCE OF METALS to corrosion sometimes seems to be more or less haphazard rather than to follow natural laws. This is because usually there are several variables present tending to prevent or accelerate the corrosion and knowledge of their relative importance has not always been available. Sometimes one variable or factor is clearly dominant and sometimes several may act together or in opposition to determine the results in actual corrosion.

To understand the service given by any alloy it is well to understand the variables which usually are the determining ones for the alloy in question. Some of the variables are conditions of the metal itself but others are conditions of the corrosive and are often such that they are not usually measured or specified.

In generalizing on the corrosion of nickel and high nickel alloys it is convenient to group the variables (other than the composition of the corrosive and the metal) into six types as follows:

1—Hydrogen-ion concentration of corrosive.
2—Air or oxidizing content of corrosive.
3—Temperature.
4—Rate of movement of metal or corrosive.
5—Electrolytic effects.
6—Surface films.

Each of these six factors has directly active effects on corrosion rates. All of them may vary in the use of the same metal in the same corrosive solution, and different factors may become dominant in their effect on the course of corrosion. Therefore, consistent corroding action is hardly to be expected just because the specified environment and metal are nominally the same.

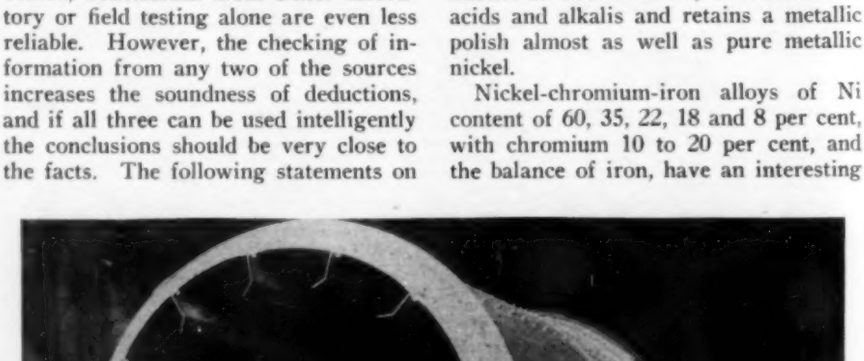
Since the variation to be expected is so great, prediction of the course or rate of corrosion should entail use of all possible sources of information. The usual sources are service experience, laboratory testing and field service testing. It is very seldom that any one of these will furnish reliable information covering all six variables. It is even insufficient to draw conclusions from

practical experience alone, as process changes which seem slight may change corrosive conditions extensively. Of course, conclusions from either laboratory or field testing alone are even less reliable. However, the checking of information from any two of the sources increases the soundness of deductions, and if all three can be used intelligently the conclusions should be very close to the facts. The following statements on the corrosion resistance of nickel and its alloys are based largely on practical experience with corroboration either by service or laboratory testing or by both.

The use of nickel as an alloy constituent in metals for corrosion resistance is wide and varied. Besides having a useful range of resistance in the commercially pure state it enters into other corrosion-resisting alloys of widely differing compositions being used in various percentages down to 1 per cent.

Pure nickel is fairly resistant to acids, alkalis and salts, is not toxic in contact with foods and retains its metallic luster well. High nickel-chromium alloys containing 80 to 85 per cent nickel and balance chromium are widely used for their resistance to oxidation and sulphurization at high temperatures and to some extent for resistance to nitric and other oxidizing acids. The type of alloy containing 60 to 70 per cent nickel, balance principally copper, usually known as Monel metal, is resistant to acids and alkalis and retains a metallic polish almost as well as pure metallic nickel.

Nickel-chromium-iron alloys of Ni content of 60, 35, 22, 18 and 8 per cent, with chromium 10 to 20 per cent, and the balance of iron, have an interesting combination of properties. They have high mechanical properties, retain these and a resistance to oxidation up to high temperatures, and become completely passive to corrosive attack in the presence of oxidizing agents and some acids. Alloys containing from 35 to 45 per cent nickel, and the balance principally copper with small amounts of other metals, make castings and drawn products (wire) resistant to mild forms of corrosion and with other valuable prop-



Steel Drum Salt Drier With Monel Metal Lining and Flights

Monel Metal Centrifuge Basket After 40 Weeks on Ammonium Sulphate Shows Little Corrosion

erties. Alloys of 20 to 30 per cent nickel, balance principally copper, are used in condenser tubing and bullet jackets.

Nickel silvers, being essentially a brass with white metallic luster due to their content of 12 to 25 per cent nickel, are prized for their beautiful finish and its retention under mild corrosion conditions. Nickel alloyed with gold to about 15 per cent changes the color to that of a white metal and the resultant alloy has all the ordinary corrosion resistance of pure gold. Nickel in the quantities used for strengthening alloy steels has never been proven to make them more corrosion resistant, but when added to cast iron in the same quantities, 1½ to 3½ per cent, it changes the structure considerably and renders the iron more corrosion resistant in certain conditions. It is used in quantities of 1 to 3 per cent in nickel bronzes and aluminum bronzes with valuable corrosion and wear resistance.

IT IS to be noted that corrosion of nickel alloys is quite different from that of chromium-iron, chromium-nickel-iron and copper alloys. The former alloys become passive in a way more intimately connected with the metal itself than do high-copper alloys. That is, there seems to be no initial corrosion with formation of a protective film but the metals remain bright and unaffected indefinitely under many conditions. Where they are affected the action is likely to be intensely localized. Nickel and high-nickel alloys from a practical standpoint corrode in an intermediate manner. That is, they have rather a definite corrosion rate, nearer that of the copper alloys than the chromium-iron alloys. This rate does not usually change with time nor does the corrosion have a great tendency to become local. They are resistant to acids, alkalis and salts, except the oxidizing acids. Alloys with proper quantities of copper or chromium are more resistant than the pure metal.

Thus the uses of pure nickel in resisting corrosion are based on certain properties rather aside from the minuteness of its corrosion rate. Probably the principle one of these is the purity of the metal. This is of great importance in two of the principal tonnage uses of pure nickel for corrosion resistance, namely, dairy work and caustic soda manufacture. In dairy work and other food handling the proved lack of physiological effect of the minute quantities of nickel absorbed make for the best purity of the product handled. In caustic soda manufacture the use of nickel eliminates the presence of other metals which may be deleterious to the caustic and introduces no disadvantageous constituents. This condition combined with the ductility and malleability, ability to produce homogeneous seams by welding, and absence of effect from physical strains, combine to make the metal useful for such purposes as cooking utensils, steam-jacketed kettles, heating coils, chemical tanks, bleaching and kitchen equipment, spark-plug wire, film manufacture, turbine blading, pyrometer wire, radio tubes, ammonia-oxidation equipment and laboratory apparatus.

The best known high-nickel copper alloy is of the type known as Monel metal. This alloy is more resistant to acids and alkalis than pure nickel and has higher mechanical properties. It is amenable to all ordinary working methods, though, due to high mechanical properties, some difficulty is experienced unless the methods used on weaker metals are modified. The fact that the composition of this alloy is very close to the metal analysis of some of the largest deposits of nickel ore has facilitated its utilization. Careful technical control has resulted in dependability of composition and this, together with metallurgical quality has given it wide use. A recent tabulation of applications where corrosion resistance is the main factor makes a list of over 1,000 major items alone. The list would be much longer if minor items were included. Thus it is impractical to list the uses here. However, some typical applications indicating the whole range will be instructive.

1—Parts to retain strength and surface finish in atmospheric exposure on aeroplanes, automobiles, buildings, refrigerators, boats and power plants.

2—Parts having resistance to acids, alkalis and salts as rods, frames, and tanks in chemical manufacture, pickling steel, textile dyeing and wet handling.

3—Operating machinery to maintain shape and strength under mechanical use and moderately high temperatures, while subjected to corrosive waters and steam in laundries, power vessels and power plants.

4—Parts to withstand simultaneous strain, abrasion and mild corrosion in chemical manufacturing and processing.

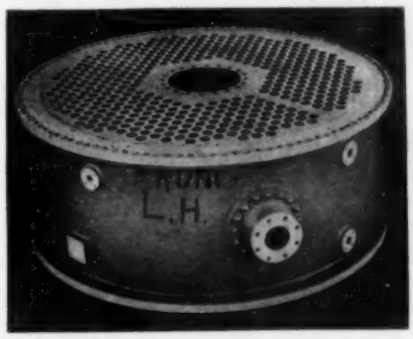
5—Parts to retain high mechanical strength and remain mechanically useable (as in bolts and nuts) in aeroplanes, buildings, pole-line hardware, and miscellaneous equipment.

6—Smooth, workable surfaces under the action of foods, fruit acids and cleaning materials as on hotel and restaurant table tops, refrigerator parts, kitchen sinks and tables, oven linings, equipment for ice cream manufacture and dispensing, and soda fountains.

7—Utensils for handling mild and strong corrosives for short periods, as, for instance, hospital utensils for antiseptics, medicines and washes, pails in laundries, bleach and dye houses and chemical manufacturing plants.

The other more important corrosion-resistant alloys of nickel are not described in this paper as they are covered elsewhere in this issue of *Chem. & Met.*, but brief mention should be made of such alloys as the nickel bronzes and malleable and cast alloys of nickel and copper with nickel contents from 20 to 45 per cent.

The addition of nickel to bronzes, in quantities of from ½ to 5 per cent, so refines the grain and increases the density of the alloy that many properties, including resistance to corrosion, are often appreciably improved. An aluminum bronze to which about 1 per cent of nickel is added has been useful in bearings, valve castings, steam-packing metal and castings to withstand high pressure and corrosion.



Steam Chest for Caustic Evaporator, 128½ In. in Diameter, With Nickel Tube Sheets and Tubes

An alloy containing about 35 per cent of nickel, with the balance copper and some chromium, makes a dense strong casting which is well fitted for service in valves handling high-pressure steam. Such valves are wet when not in use and may be affected not only by water from clean steam but by any impurities in the form of gases which the steam carries. When used as controls for the flow of steam, the effects of erosion and corrosion together are quite serious and this alloy withstands them well.

Compositions of 20 to 30 per cent nickel, balance copper (one exceptionally good alloy contains 1 per cent of tin), are particularly resistant against the corrosion due to salt water in such

service as condenser tubes for power plants along tidewater where salt water is an economical cooling medium.

A few words concerning the determination and expressing of corrosion resistance of nickel alloys seems appropriate in view of the many honest mistakes that have been and are being made, in application of alloys in new uses. We have said above that there are three general methods of determining corrosion resistance: plant experience, field or process test and laboratory

test. None of these are infallible and none give exact quantitative results.

Plant experience is the most reliable source of information and yet it may fall short for many reasons. Prominent among these are the lack of variability in operating apparatus, difficulty of making accurate observations and lack of information on the variables which actually affect corrosion. In modern development, processes are changing rapidly and last year's experience may not be of much use next year. I have in mind two important cases, one where an invention produced a new use for a chemical product and changed the former purity requirements. This forced the manufacturers to discard the experience of years and build apparatus of a different material. The new material was selected on the basis of laboratory and field tests which checked each other. It was completely successful and no failures have occurred in subsequent installations where the results of these field and laboratory tests have been used. Failures have occurred where they were not used.

In another case development of refining processes on a widely used product made higher temperatures necessary. The change caused several failures of a metal used for a part of the refining apparatus. As there are no laboratory or field tests or experience available on suitable alloys for the new conditions, the material for these parts is still unstandardized after several years of trial and error.

THUS years of experience may cover conditions so unvarying that a slight change in process may render them unreliable. Experience, therefore, should be supplemented by field or laboratory tests when changes in materials, processes, or design are in order.

Both field and laboratory tests can yield valuable information if, when they are made, recognition is given to the limitations of the tests in view of the variables which determine corrosion rates and conditions. Any complete description of methods used on nickel alloys is out of place here, but certain main facts may be mentioned. The first thing at which to aim is duplication of service conditions in regard to the six factors mentioned above and any others peculiar to the particular case. Often such duplication is not easy. Acceleration is a second possible but dangerous step and should not be undertaken until duplication is assured. This necessity of duplication is too often neglected and the following list of errors which have been experienced through this neglect should be carefully noted:

A small metal sample held in a container of acid shows inappreciable weight loss after exposure, but when the same acid is handled in a tank of the material under test the discoloration due to slight corrosion is too great to permit use of the metal.

A number of clippings of sheet metal placed in a beaker of a corrosive cause rapid deterioration of the corrosive due to large areas of small pieces and concentration cell action at contact points. On the other hand, the metal is quite useful for tanks handling the corrosive because the relative area of metal is less and concentration cells are absent.

Two metals, one of which forms a protective film immediately and the other slowly, are tested in a tank for their suitability as a lining. When removed after a short test, the second metal looks much less applicable. But in use it forms a completely protective coat while the first, with its relatively thin original film, becomes badly pitted in time.

Two metals, one subject to rapid attack by dissolved oxygen and the other protected by exposure to it, are tested in an apparatus which lowers and raises the samples in and out of a solution. They are also immersed quietly in the same solution in a closed container. Results of the two comparisons are opposite. Such results are only applicable to conditions comparable with those of the test.

A metal which forms a protective coat slowly, corrodes away rapidly when tested in a flowing stream, but may be entirely suitable for a storage tank.

A metal, highly resistant to a corrosive in itself, may produce electrolytic effects which rapidly destroy any available seaming material; or may be susceptible to electrolytic concentration cell attack where joints occur in apparatus.

A small sample in a large tank may be rapidly corroded by some material occurring in small quantities, as dissolved air, whereas if the whole tank were built of the metal this corrosion would not be noticeable.

It becomes evident from the above that quantitative expression of corrosion resistance usually is in need of quite an involved description of the limitations or conditions. In fact corrosion resistance as such hardly is capable of expression in such definite terms as are tensile strength and composition. The writer recommends the use of two quantitative units in expressing results: (1) Milligrams per square decimeter per day weight loss, for use by those actively studying corrosion and (2) penetration in inches per year, referring either to weight loss or pitting depth, for designing engineers. These units are useful in designating change in rate in a series of tests and in comparing one series of tests with another. But when such units are used they should be qualified by a definition of the factors, six or more, known to influence them.

ANOTHER way of expressing results is a blanket statement as to suitability of an alloy for a given defined condition. It is obvious that such a statement must be made in the light of defined conditions of the factors mentioned above. But it also must be made in the light of many practical points affected by the corrosion resistance and other properties. A metal may be suitable for tanks but not for pipe lines. It may be suitable for a given use as forgings but not as castings. It may make good tank linings but poor mechanical parts such as shafts or beams. It may be susceptible of perfect seaming for one acid, but there may be no suitable seam for another. It may last indefinitely if unstrained but fail quickly under strain. It may be suitable in centrifugal but not in reciprocating pumps, and so on in endless variations. Thus companies which have had many years of experience in recommending alloys for special uses and supporting these recommendations will usually ask for exact definition of the prospective use before rendering an opinion.

In conclusion it may be said that nickel and the high nickel alloys, while very widely useful in resisting corrosion, are most useful where their limitations are well understood. They are corroded by some solutions under all conditions and by all solutions under some conditions. But their field of cor-

rosion resistance, combined with the many other properties which determine their use as well, is a broad one which has only been touched upon in this article. The use of the alloys containing both low and high quantities of nickel is now so common that information on a wide range of proved and indicated uses is available. The information is of such a nature that not all of it can be published, but it may be readily obtained by application to the service departments of the various manufacturing companies.

How Chemical Industry Applies

COPPER AND COPPER ALLOYS

By William H. Bassett

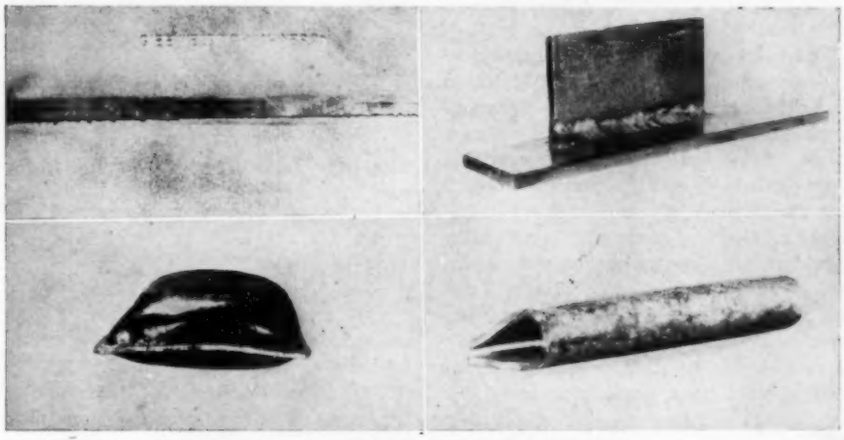
Technical Superintendent, American Brass Company, Waterbury, Conn.

IN AN EARLIER article by the writer (*Chem. & Met.*, October 1926, pp. 618-19) the characteristics and applications to chemical industries of a number of non-ferrous alloys were described. The study of corrosion is now well recognized as an important branch of metallurgy, and producers are devoting considerable energy to improvement and development of corrosion-resistant alloys. It is my purpose to summarize briefly the data presented in the previous paper, supplementing it with a description of advances that have been made during the past three years with copper and the copper alloys.

Among the copper materials which are finding extensive use in chemical industries, often under severe conditions, may be mentioned: deoxidized copper, red brass, aluminum bronze, Tempaloy, Ambrac, and Everdur.

The first, deoxidized copper, is the product resulting from the deoxidation of electrolytic copper, containing a minimum of 99.90 per cent copper, by the addition of phosphorus or some other agent that will remove the oxygen with which such copper is naturally alloyed. The tensile strength of copper may vary from 35,000 lb. per square inch for soft material to 55,000 lb. per square inch for that which has been cold worked. The elongation in 2 in. varies from 35 per cent soft to 5 per cent hard.

Copper tubes, which, according to American practice, are of deoxidized copper, are extensively used in various types of chemical and engineering apparatus such as heaters, coolers and evaporators. The resistance of copper to corrosion by many organic and inorganic acids makes it useful in sugar refineries, soap works, sulphite pulp mills, and in the manufacture of many chemicals. Copper is used also for carrying refrigerating brines and in mechanical refrigerators where it conducts sulphur dioxide, ammonia, or carbon dioxide. It is important in the paper industries, where it carries pulp and water in paper mills and also transports washed pulp from the pulp mill to the paper mill, particularly where these units are separated some distance from each other.



Examples of Weldability of Everdur Metal

Above at the left is a sample of continuous seam made with an automatic welder. At the right is a corner or fillet weld. The lower left shows Everdur welded together for a hydrostatic test, and the lower right, a bend test on a butt-welded joint

Red brass is a corrosion-resistant material the value of which has been demonstrated by laboratory and service tests extending over the past 16 years. This alloy is composed of 85 per cent copper and 15 per cent zinc, and is a solid solution which exhibits no tendency toward "corrosion-cracking" when exposed in strained condition, or to selective attack or disintegration. It possesses tensile strength of 43,000 lb. per square inch and elongation of 43 per cent in 2 in. in the annealed condition. It has a tensile strength of 75,000 lb. per square inch with an elongation of 4 per cent in 2 in. when work-hardened.

Table I—Nominal Compositions of Aluminum Bronzes

Alloy	Cu	Al	Fe	Sn	Forms Produced
5 per cent aluminum bronze	95.0	5.0	...	...	Sheet, rod, wire
8 per cent aluminum bronze	92.0	8.0	...	...	Sheet, rod, wire
Special aluminum bronze.....	89.5	8.0	2.5	...	Sheet, rod, strip
Calsun bronze..	96.1	2.3	...	1.6	Wire, rod
Avialite.....	89.7	9.3	1.0	...	Rod, hot pressed parts, sheet, strip
Special avialite.	88.0	10.5	1.5	...	Rod

Red brass is superior to tin bronze in its resistance to the corrosion of most acid and salt solutions. The pipe is used for unusually severe water conditions, where material better than ordinary brass pipe is required. It is also used for carrying sludge acid in oil refineries, and for carrying "acid" to and from the digesters in sulphite pulp mills. After exhaustive tests the U. S. Navy has adopted red brass as a standard alloy for service pipe conveying sea water on shipboard and at shore stations. It is recommended for both hot and cold seawater service.

Aluminum bronzes are used where the combination of strength with resistance to corrosion and wear is essential—as, for example, pump parts and diaphragms, acid pickling equipment, valve seat inserts for internal combustion engines, Jordan bars for paper manufacture and similar uses.

A number of different compositions of aluminum bronzes are in common use, the composition depending on the physical properties desired. The tensile strengths of the various aluminum bronzes range from a minimum of 55,000 lb. per square inch as annealed to a maximum of 130,000 lb. hard drawn, the actual strength depending on composition and metallurgical treatment. The elongation in 2 in. varies from 4 per cent hard to 75 per cent soft. The nominal compositions are tabulated in Table I.

A recent development which undoubtedly will prove of importance in engineering uses is the hardened copper patented by Corson in 1928. This is known by the name Tempaloy, and has the approximate composition, 95 per cent copper, 4 per cent nickel, 1 per cent silicon. When heated to 750-800 deg. C., the nickel silicide goes into solid solution, and if chilled from this temperature, the alloy is soft and ductile. When heat treated at approximately 450 deg. C. for several hours, the nickel silicide is precipitated and the material becomes hard and strong, resembling mild steel in its physical properties. The reaction is similar to that which takes place in hardening Duralumin by heat treatment or aging.

Tempaloy rod of ⅝-in. diameter, after cold drawing, had a tensile strength of 71,200 lb. per square inch and a Brinell hardness of 133 (1,000 kg. load, 10 mm. ball). After heat treatment the tensile strength was 113,800 lb. per square inch and the Brinell hardness 204.

The addition of aluminum to this alloy considerably strengthens it and accentuates the hardening properties. Tempaloy to which 5 per cent aluminum has been added has a yield point of 25,000 lb. and tensile strength of 65,000 lb. per square inch after quenching from 800 deg. C. When heat treated at 450 deg. C. the yield point is 100,000 lb. per square inch and the tensile strength 130,000 lb. Addition of larger quantities of aluminum to this alloy has resulted in material having a tensile strength of 150,000 lb. Tempaloy is still in the development stage.

Table II—Nominal Composition of Ambrac

Alloy	Copper	Nickel	Zinc
Ambrac "A".....	75	20	5
Ambrac "B".....	65	30	5

Among the best of corrosion-resistant materials are the high-copper nickel alloys. These alloys are strong and particularly resistant to general corrosion, of excellent appearance, and not subject to "corrosion-cracking." They may be easily wrought either hot or cold and are available in the form of sheets, bars, strips, rods, wires, tubes, castings, and shapes. Dependent upon heat and mechanical treatment, a wide range of physical and mechanical properties may be obtained. The nominal composition and physical properties of two much used alloys of this type, Ambrac "A" and "B," appear in Table II. Table III shows certain physical properties of Ambrac "A" at elevated temperatures.

Ambrac "A" exhibits tensile strength ranging from 50,000 lb. per square inch in the soft sheet to 110,000 lb. in hard-drawn wire, with yield points (taken as the stress producing an elongation of 0.75 per cent) of 24,000 to 80,000 lb. per square inch. In the form of castings, a tensile of 40,000 lb. is to be expected. Ambrac "B" possesses slightly better physical properties and has somewhat better corrosion resistance under certain conditions. In this case the tensile strength ranges from 65,000 lb. to 130,000 lb. per square inch with yield point variations of 29,000 to 95,000 lb. per square inch.

Ambrac is extensively used to resist salt solutions, alkaline solutions, dilute sulphuric acid, and many other types of exposure. Recommendations for these uses must, however, be based on more extensive information than that pertaining simply to concentrations and temperature of the corroding medium. In the case of any metal or alloy, such conditions as aeration, pressure, motion of the liquid, presence of other chemicals, and contact with other metals may exert a profound effect upon the suitability of the metal. Since corrosion problems are so extremely complicated, the ultimate

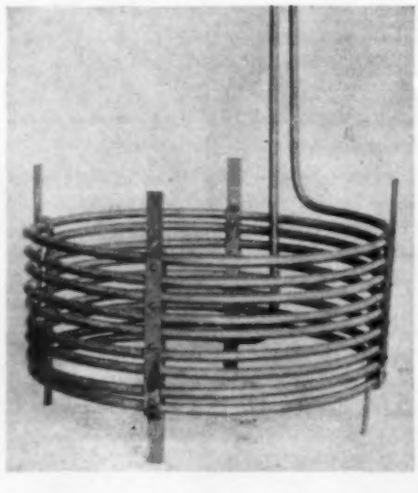
Table III— Ambrac "A" Cold-Drawn Rod at High Temperatures

Temperature, Deg. F.	Ultimate Strength, Lb. per Sq. In.	Elongation in 2 In., Per Cent
72	63,180	13.3
518	53,350	11.5
788	43,290	10.0
968	33,720	10.5

solution must be arrived at by an intelligent study of the problem.

The value of Ambrac for condenser tubes is rapidly becoming recognized both in this country and abroad. The copper-nickel alloys of this type are especially resistant to impingement attack, or local corrosion at the entrance of the tube. Ambrac tubes installed in a gasoline condenser in one of the large oil refineries three years ago, subjected to the action of gasoline vapors carrying hydrochloric acid and sulphides on the inside and to that of brackish cooling water on the outside, are still in good condition and in active service at the present time. In certain marine condenser installations Ambrac has given much longer service than the standard Admiralty alloy.

Heating Coil Constructed Entirely of Everdur Tubes



Ambrac is of further application in the handling of hot and cold salt brines and in the conveying and evaporation of caustic soda solutions. It is resistant to dilute chlorine bleach solutions and to dry NH_3 gas or liquid. It is not recommended for moist ammonia.

Table IV— Hot-Rolled Everdur Rod at High Temperatures

Temperature, Deg. F.	Ultimate Strength, Lb. per Sq. In.	Elongation in 2 In., Per Cent
80	72,650	43.5
500	60,200	33.0
750	35,930	25.5
1,000	14,480	18.0

Of particular interest to the chemical industries is Everdur metal, a copper-silicon-manganese alloy patented in 1925 by Jacobs of the duPont company. In addition to excellent corrosion resistance this alloy possesses the strength of mild steel. The composition of Everdur to be used in casting is 94.8 per cent copper, 4 per cent silicon, and 1.2 per cent manganese. Wrought Everdur has the composition 96 per cent copper, 3 per cent silicon, and 1 per cent manganese. A number of the physical properties at elevated temperatures are shown in Table IV.

Everdur is being used for bolts, screws, nails, pipe, fittings, pump casings, and valves where corrosion-resistant material is required; for ventilating fans, ducts, louvres, and eliminators for storage battery or plating rooms; for steel mill pickling equipment; for handling sludge acid in oil refineries; fittings or stills in soap works; fiber plant equipment; gates or screen frames for water supply reservoirs and for sewage plants. It is being used for hot water storage tanks on account of being inert to hot water action and because of the ease with which it may be welded.

Table V— Characteristics of Welding Materials

For Oxy-Acetylene Welding

Metal	Melting Point
Tobin bronze.....	1625 deg. F.
Manganese bronze.....	1598 deg. F.
Brazing metal.....	1634 deg. F.
Deoxidised copper.....	1981 deg. F.
Electrolytic copper.....	1981 deg. F.
Naval brass.....	1625 deg. F.
Everdur.....	1866 deg. F.
Ambrac.....	2102 deg. F.

For Arc Welding

Metal	Melting Point
Phosphor bronze.....	1922 deg. F.
Everdur.....	1866 deg. F
Ambrac.....	2102 deg. F
Deoxidised copper.....	1981 deg. F

Comprehensive tests made under actual operating conditions in a sulphite pulp mill showed that the corrosion resistance of Everdur was at least equal to that of 10 per cent tin bronze, which has been successfully used in this service for years.

Everdur has a decided advantage over many alloys in its ability to resist hydrochloric acid. It has proved satisfactory for use in tanks, pumps, valves, pipe and fittings for all strengths of cold acid, and for hot acid up to 20 per cent at 70 deg. C., in the absence of air and steam. It has been satisfactory in han-

dling hot, dilute sulphuric acid solutions, cold acid to 95 per cent, and mine waters of certain types, particularly where ferric sulphate is absent. When air is excluded, acetic acid of any concentration as well as the anhydride may be used with Everdur.

Table VI— Strength of Welds in Copper Alloys

Deoxidised copper...	25,000 to 30,000 lb. per sq.in.
Phosphor bronze....	25,000 to 35,000 lb. per sq.in.
Ambrac.....	30,000 to 40,000 lb. per sq.in.
Everdur.....	40,000 to 50,000 lb. per sq.in.

In addition to its uses depending on resistance to corrosion, Everdur is finding extensive use also for engineering purposes where a corrosion-resistant material having the strength of steel is necessary.

In the construction of apparatus and equipment for chemical industries, the ease with which a material may be welded is a factor of major importance. In addition to physical properties, the composition of the welding material should be given due consideration. It is well known that when couples of dissimilar metals in contact with each other are exposed to corrosive solutions, the less noble will be selectively attacked and corrosion will be accelerated by contact with a more noble metal. It is therefore of the utmost importance, in the fabrication of apparatus and equipment for severe service conditions, that the welding material be of such composi- will take place. Generally it is safe practice to use for welding a material of practically the same composition as the material to be welded. All of the alloys described above may be readily welded, and welding rods of the proper composition are commercially available. Data concerning welding materials are given in Table V. The strength of welds when used to join metals of composition similar to that of the welding material is shown in Table VI.

◆

TANTALUM—*A Metal for Difficult Corrosion Problems*

By Chester H. Jones

Fansteel Products Company, New York

METALLIC TANTALUM, it should be noted, is an elementary metal and not an alloy. As produced commercially it has a purity of at least 99.5 per cent. Reference to a periodic table will show the proximity of tantalum to columbium, the sister metal, and to molybdenum and tungsten. Tantalum bears the same relation to columbium that tungsten does to molybdenum in general characteristics.

Remarkable strides have been made in the introduction of tantalum to various phases of industry. Being a noble metal it is rather high in cost, selling for a price of about one-fourth the value of gold, but where it is found of use its characteristics justify this cost.

The cost of tantalum is due mainly to the expense of extracting it from its ores and to the price of the ore itself. This ore, containing over 60 per cent Ta_2O_5, comes from the desert region of northwestern Australia and is shipped direct to the refinery at North Chicago, Ill. Long technical processes involving the use of highly corrosive solvents and large quantities of electric power are employed in the separation and production of the wrought metal.

Tantalum was known in ores as early as 1801 but it was not until 1903 that it could be separated from columbium in even the most impure condition. The metal, as now produced on an extensive commercial scale, is more easily obtained in the pure state.

The first important use of tantalum since its introduction as a lamp filament by Von Bolten in 1903, a use which extended to 1911, has been its employment as an electrolytic rectifier in sulphuric acid with lead as the other electrode. This use of tantalum probably will continue indefinitely in connection with rectifiers and condensers on railway signal systems and in telephone and telegraph work.

One of the largest of present uses of the metal is in connection with the elements of vacuum tubes employed in radio receiving and broadcasting, in X-ray work and other like purposes, and in Neon lights. The principal characteristic which makes it of value in the vacuum tube is its ability to absorb all gases and metallic oxides present when it is brought to a red heat. Thus it operates as a continual cleaner-up or "getter" of gas impurities in these tubes. Tantalum will absorb 740 times its volume of hydrogen gas. This absorption begins at a low red heat, about 350 deg. C.

Another use now in the final stages of development is the application of tantalum to pen nibs instead of gold. Advantages include lower cost and more economical fabrication.

A field more closely allied to chemical engineering is the use of tantalum as a material for spinnerettes in the production of rayon. In addition to excellent corrosion resistance, the metal has the further advantage that it can be coated with an electrolytic oxide of almost diamond hardness so that there is no apparent wear or distortion of the holes through which the spinning solution is ejected. Both tantalum and the oxide coating referred to above are inert toward all chemical reagents except hot fused caustic, hydrofluoric acid, mixtures of hydrofluoric and nitric acids and 95 per cent boiling sulphuric acid. The metal is inert toward aqua regia and toward wet or dry chlorine.

Other individual applications of tantalum in the process industries have been numerous. Since it can be successfully spot welded to iron or steel, it has, for example, been used as a lining or cover for pipes and various other shapes where the expense is justified by the results obtained.

Various kinds of laboratory apparatus are now fabricated from tantalum because of its corrosion resistance and mechanical strength. It has a tensile strength in wire form of 130,000 lb. per square inch. The texture of the metal partakes more of the nature of a closely woven wood fiber than the grain structures ordinarily existing in the common metals. It is easily fabricated in forms ranging from heavy bars down to very thin sheets and very fine wires.

The principal limitation to use of tantalum is that it cannot be brought above a temperature of about 350 deg. C. without absorbing gases present and undergoing deterioration. If the metal is used hot it must be in a high vacuum. When used cold, it appears that platinum only among noble metals has properties which rival it.

Physical Properties of Tantalum Compared With Tungsten and Molybdenum

	Tantalum	Tungsten	Molybdenum
Atomic weight	181.5	184	96
Specific gravity, at 20 deg. C	16.6	19.3	10.2
Tensile strength, lb. per sq. in.	130,000	490,000	260,000
Brinell hardness at 500 kg	45.9	290	147
Young's modulus of elasticity, kg. per sq. mm.	19,000	42,200	....
Melting point deg. C.	2,850	3,370	2,620
Specific heat cal. per gm. per deg. C., at 0 deg. C.	.0365	.0336	.0647
Linear coefficient of expansion per deg. C.	7.9×10^{-6}	4.44×10^{-6}	5.45×10^{-6}
Heat of combustion cal. per gm. atom to oxide	300,120	191,400	173,950
Temp. coefficient of resistance at 20 deg. C.	.0031	.0045	.0033
Electrical resistance microhm per cu.cm. at 20 deg. annealed	15.5	5.51	5.7
Electrochem. equiv. mg. per coulomb	.3762	.31788	.1658
E.m.f. against copper micro-volts per degree	4.1	4.5 (Above 200° C.)	....

Unfamiliar Uses Increase TIN *Applications*

By Charles L. Mantell
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TIN, from the chemical engineering viewpoint, has few applications as a material of construction in the process industries. Where it can be used, however, it is decidedly superior to other metals.

The metal is attacked by inorganic acids both oxidizing and non-oxidizing, the attack being accelerated by the presence of oxygen or oxidizers. It is not resistant to corrosion by bases or salts. It is thus automatically eliminated from consideration as a material of construction in almost all branches of the chemical industries. Therefore, it might be expected that potassium dichromate or sodium dichromate, being strong oxidizing agents, would greatly accelerate the corrosion of tin in non-oxidizing mineral acids. As a result of the formation of an insoluble coating on the metal, however, the tin is protected from further destruction, and potassium and sodium dichromates are thus found to have passivating action instead of accelerating corrosion.

Even the purest water has practically no solvent action on pure tin. Long experience has shown that block-tin pipe, when the metal from which it is made is of good quality, is one of the best materials for conveying distilled water to be used for experimental purposes. Carbonated water also has practically no solvent effect on tin metal.

OXIDATION of tin is absent at ordinary temperatures, commencing at 100 deg. C., taking place only at a low rate. Below 200 deg. C. tin is oxidized more slowly in moist than in dry oxygen, as a result of the formation of a partially protective coating.

Tin is widely used in alloys, in the manufacture of tin foil, and for coating other metals, such as copper and iron, to render them more resistant to corrosion, or for decorative effects. Tin metal is very resistant to corrosion by the atmosphere and by various atmospheric constituents which result from manufacturing processes. Were it not for the fact that tin is electro-negative to iron, and hence strongly accelerates its corrosion in the presence of atmospheric electrolytes when the two metals are exposed at the same time (that is, if the coating be non-continuous) tin would serve admirably as a protection to sheet steel or iron.

In some respects tin is an almost ideal coating metal. It can be applied as an extremely thin coating uniformly distributed over the surface. Tinned sheet metal can be very severely deformed without material damage to the coating, hence it is admirable material for forming operations. So long as the coating is intact, it gives excellent protection to the metal beneath from corrosion, but it affords no protection in an electrochemical way as zinc does after the underlying metal has been exposed.

Some specialized applications of tin will be considered, as well as specific places in which its use is to be avoided. Jones (*Chem. Age*, London, Vol. 4, 1921, pp. 394, 416) states that tin metal resists oleum very well and is useful in making condensing coils where copper

would be attacked. The advisability of the use of tin in this connection is questionable, inasmuch as it can be supplanted by cheaper metals which have sufficient corrosion resistance. Pure liquid hydrocyanic acid has no action on pure tin and probably none on commercial tin. But it is believed that contact of this acid with commercial tin causes decomposition of the acid, and that the use of tin in connection with hydrocyanic acid should be avoided.

Data obtained from corrosion studies clearly indicate that acetic acid may be safely handled in tin, at least up to 60 per cent concentration. It is quite possible that at room temperatures somewhat higher concentrations may be stored in tin or tin-lined containers. The results also show that boiling acetic acid should not be handled in tin in concentrations much over 20 per cent.

The moist vapors of salicylic acid do not affect tin when the metal is used as a condensing surface. When the vapors of salicylic acid are condensed in iron equipment, they are given a violet coloration; but there is no discoloration when tin equipment is employed.

In the manufacture of tartaric acid, where large crystals are desired, most recent practice employs shallow block tin crystallizing pans. The use of other metals introduces undesired metallic impurities in the finished product.

Tin gives satisfactory resistance to solutions of sodium hydrosulphite. The best materials of construction to insure cleanliness of this product are tin, nickel and Monel metal. They not only withstand corrosion by solutions and suspensions of the salt itself, but also by the other reagents that are encountered in the process of manufacture. This does not, however, include the first step of the process—that is, digestion.

THE ACTION of photographic solutions has been studied by Crabtree, Hartt, and Mathews (*Ind. & Eng. Chem.*, Vol. 16, 1924, pp. 13, 81). Tin is one of the least suitable metals for use as a material of construction for apparatus used in handling and conveying photographic developers and fixing solutions. Practically all the other non-ferrous metals are more suitable. Tin, solder, or any alloy containing tin should not be used in developing apparatus.

Drugs such as caffeine, even up to 20 per cent solution, or caffeine containing small quantities of sodium salicylate, have no solvent action on tin either at ordinary or at elevated temperatures up to the boiling point.

The widespread use of tinned apparatus in the production, transportation and preparation of milk and milk powders leads one to the belief that the metal has been found by experience to be exceedingly satisfactory for this work. Although sweet milk has practically no corrosive effect on tin metal, irrespective of exposure or temperature, sour milk, due to the lactic-acid content, readily corrodes the metal.

Tin plate seldom finds use as a chemical engineering material of construction, but multitudes of products of the process industries are packaged in tin-plate containers such as cans and boxes. The widespread use of these for chemical products, paints, oils, solvents and similar materials indicates the suitability of tin plate for this work.

Tin, particularly as a coating on copper and non-ferrous metals, finds extensive use as a preferred construction material in the food processing industries, in the form of kettles, pots, cookers and similar equipment. Its salts are non-toxic and colorless. It satisfactorily withstands the action of food products.

In conclusion, some mention should be made of the use of tin in alloys, particularly tin-copper alloys, such as the sea-water bronzes, the gun metals, and phosphor bronze. Phosphor bronze resists the corrosion of sea water better than copper, and mine waters better than iron and steel. Many of the so-called hydraulic or high-pressure bronzes are markedly resistant to the corrosion action of steam and condenser water.

SILVER

A Metal of Specialized Use in Chemical Plants

As a construction material, silver always has been regarded as a metal whose price forbade its use. Silver is the only metal whose chloride is insoluble; it would appear to have possibilities of being a material to resist chlorides, exposed to which practically all our metals fail. Silver, however, is not unusually resistant to the halogens and halide salts. It is attacked by acids, discolored and corroded by sulphides and sulphur compounds but is resistant to bases in that alkalis can be fused in silver crucibles. Silver is insoluble in liquid ammonia. Most salts attack the metal. It is less resistant to solution by water than is tin.

Frederick Pope, in discussing the equipment of synthetic phenol plants (*Met. & Chem.*, Vol. 15, 1916, p. 690), states that the refining still for phenol should contain silver tubes and all portions of the condenser coming in contact with the finished phenol should be silver or silver-lined. The pipes from the condenser through the watch glass to the phenol tank should be silver-lined and the valves, of the flanged-gate type, extra heavily silver plated. The phenol receiving tank should be enamel-lined and all valves in connection with it should be of silver or silver plated.

With the displacement of the silver standard for coinage by the gold standard in large consuming countries like India, silver has become cheaper. It may, as a result, find minor uses as a construction material in the process industries when the bogey of "too expensive" is not such a frightening one.

❖

TANTALUM

Proves Economical for Calorimeter Body

By G. C. Maier

Acting Supervising Engineer, U. S. Bureau of Mines Pacific Experiment Station, Berkeley, Calif.

In the course of its program of study of the fundamental properties of metallurgically important materials, the Pacific Experiment Station of the U. S. Bureau of Mines more than a year ago constructed a new type of precision calorimeter for studying the dissolution of metals and oxides in strong acids. A part of the calorimeter is a cylindrical can with hemispherical bottom and flanged top, which must withstand the action of strong mineral acids for long periods of time. In one series of experiments it was necessary to subject material to the action of 2.5 normal hydrochloric acid; in other experiments acidulated copper solutions of a very corrosive nature were used.

A tantalum and Bakelite construction, which has been in constant use for more than a year, has proved not only ideal with respect to corrosion but also decidedly economical. For materials of construction of this sort experimenters in the past have used platinum or gold. The container if made of platinum would cost $1,500 and if made of gold, $300, for metal alone; but made of tantalum it cost actually only $150 completely fabricated. If it had been made of gold, difficult reinforcing problems would have been encountered because fine gold would have to be used. Neither platinum nor gold has the mechanical strength of tantalum. The mechanical usage has been severe, as the contents of the container are constantly stirred, and at one step of the experiments glass containers are smashed directly upon the hemispherical bottom. The seams of the apparatus, which is made of 10 mil sheet, were roller-welded and have not given the slightest trouble; nor has there been any trace of corrosion.

The economy of tantalum for the solution of laboratory problems of the type described probably is not as widely or generally recognized as the usefulness of the material justifies. Even if tantalum cost as much as gold its great mechanical strength and toughness would justify its use.

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PRECIOUS METALS

for

Ultimate Corrosion Resistance

By Frederic E. Carter

Research Department, Baker & Company, Newark, N. J.

When we read statistics of the huge quantities of such metals as iron, copper, aluminum and nickel used in industrial plants and then glance at the total ounces of the precious metals commercially employed, we might readily be excused if we assumed that the latter were industrially unimportant. However, such an assumption would on deeper scrutiny prove to be very far from the truth. The "make and break" in a power supply, the spinnerette in a rayon plant, the catalyst in a chemical process, or the thermocouple in a furnace may be inconspicuous enough, but the quality of the product, perhaps even the success of the process, will often depend on the reliability of these small parts. It is in such small but essential functions that we generally find the "noble" metals at work.

The platinum group consists of six metals which, although having certain points of difference, show a general resemblance to one another in most respects; the group may be divided further into two sub-groups, as follows:

A	Platinum	21.40 sp.gr.
	Iridium	22.42 sp.gr.
	Osmium	22.50 sp.gr.
B	Palladium	12.16 sp.gr.
	Rhodium	12.44 sp.gr.
	Ruthenium	12.10 sp.gr.

It will appear that the metals of sub-group *A* are almost twice as heavy as those of sub-group *B*. In addition to numerous points of similarity between the members of each sub-group, there also are many chemical analogies between corresponding members of the two groups. Thus, platinum and palladium, iridium and rhodium, osmium and ruthenium may be looked upon as pairs. Gold, having a specific gravity of 19.33, is not quite as dense as the *A* sub-group above.

The properties of the platinum metals and gold, which make them of value in the chemical industry, are:

1—Resistance to chemical reagents.
2—High melting point.
3—Non-oxidizability.

In general the precious metals show great powers of withstanding chemical reagents. Aqua regia has no effect on iridium, osmium, rhodium or ruthenium, but it does readily dissolve platinum, palladium and gold. No single acid has any appreciable dissolving action on any of the metals, except in the case of concentrated nitric acid on palladium,

Chemical Properties, Gold and Platinum-Group Metals

A = unaffected; B = slightly affected; C = considerably affected; D = useless

Corrosive		Au	Pt	Ir	Os	Pd	Rh	Ru
H_2SO_4 Conc.	Cold	A	A	A	A	A	A	A
	Hot	A	B	A	A	C	A	A
HCl Conc.	Cold	A	A	A	A	A	A	A
	Hot	A	A	A	A	A	A	A
HNO_3 Conc.	Cold	A	A	A	A	C	A	A
	Hot	A	A	A	A	D	A	A
Aqua Regia Conc.	Cold	D	D	A	A	D	A	A
	Hot	D	D	A	A	D	B	A
HF		A	A	A	A	A	A	A
NaOH	Fusion	A	B	A	C	A	B	B
Na_2O_2	Fusion	D	D	C	C	D	B	C
Na_2CO_3	Fusion	A	B	A	B	A	B	A
$KHSO_4$	Fusion	A	B	A	B	B	C	A
Alkali nitrates	usion	A	A	A	D	C	A	A
Alkali cyanides	Fusion	D	B	A	A	B	A	A

which it readily dissolves. Hot concentrated sulphuric acid attacks platinum slightly but no other acid has any effect on the remaining metals. If it is desired to bring the more insoluble metals into solution, they have to be alloyed with some other metal like lead or zinc, and then treated.

It is sometimes preferable to use a platinum alloy instead of platinum in chemical apparatus. In an alloy composed of a noble metal and a base metal, the base properties are completely masked until a certain percentage of the base metal is reached; for example, platinum containing up to 25 per cent palladium is unattacked by nitric acid, even though palladium is readily attacked. In a similar manner gold protects palladium, copper or silver in alloys high in gold from HNO_3 attack.

THE METALS are readily attacked by many of the non-metals like phosphorus, arsenic, silicon and carbon. The caustic alkalis, the alkaline earths, the alkali cyanides, and a few other reagents attack the platinum metals at a red heat, but in general platinum and its fellow members are remarkably inert to chemicals. All the halogens attack the different metals in varying degrees; they attack iridium, rhodium, osmium and ruthenium either very slightly or not at all; nascent chlorine, the active agent of aqua regia, readily dissolves platinum and palladium; iodine dissolves palladium, giving the characteristic palladium iodide, and fluorine attacks platinum at a dull red heat. Gold dissolves in potassium or sodium cyanide; also in selenic acid.

With the exception of gold the melting points of the precious metals are very high. The temperatures are given in the table and although the figures are accurate for the metals melting below 2,000 deg. C., those given for iridium, ruthenium and osmium must be taken as approximations only.

Neither the platinum metals in compact form nor gold oxidize at ordinary temperatures, and it is for this reason that the individuals of the group are called "the precious metals." This general stability does not hold, however, for higher temperatures. For instance, osmium and ruthenium readily oxidize to form volatile oxides on heating. Also, at about 600 deg. C. palladium begins to oxidize and become coated with various-hued oxides; at a few hundred degrees higher the oxide decomposes again, giving palladium and evolving oxygen. Iridium acts in a somewhat similar way; if it is heated, for instance, in an electric furnace to about 900 deg. C., it becomes coated with a colored oxide which readily decomposes at somewhat higher temperatures. Platinum and rhodium, although they actually form transitory oxides, which are stable only within narrow ranges of temperature, may be said for all practical purposes to be non-oxidizable at all temperatures.

Platinum apparatus was formerly used in industry on quite a large scale (for example, sulphuric acid was concentrated in large platinum vessels), and although the high cost of the metal has brought about the introduction of substitutes, considerable amounts of platinum, gold, or their alloys, are still used in special processes where the material would attack any metal or alloy other than those of the precious-metal group. Platinum vessels are used to some extent in the purification of hydrofluoric acid.

Probably the largest amounts of the platinum metals that are used in the chemical industry are used in the form of catalysts. The modern method of making nitric acid is to pass air and ammonia in a ratio of about 10 to 1 through a platinum gauze. The gauze is now generally made of platinum-rhodium alloys instead of platinum, and the reaction takes place with almost 100 per cent efficiency. In most modern chamber sulphuric acid plants niter pots are dispensed with and the necessary nitrous gases are produced in a relatively minute ammonia-oxidation unit in the same manner as in the process for direct production of nitric acid. Large quantities of platinum are still used for the catalyst mass of the contact sulphuric-acid process and the use of platinum metals as catalysts in the rapidly developing synthetic organic-chemical industry is increasing.

The electrochemical industry requires in certain electrolytic baths (e.g., potassium chlorate production) platinum or gold electrodes, since no satisfactory inert substitute has been found.

There is a rapidly growing field for electroplating with the platinum metals. This includes, in addition to its purely decorative value, the plating of instrument parts, electrical sockets, and so on.

The increasing use in industry of alloys whose properties are determined

Physical Properties, Gold and Platinum-Group Metals*

	Au	Pt	Ir	Os	Pd	Rh	Ru	Units
Atomic weight	197.2	195.2	193.1	190.9	106.7	102.9	101.7	
Specific gravity	19.33	21.40	22.42	22.50	12.16	12.44	12.10	Grams per c.c.
Melting point	1,063	1,755	2,350?	2,700?	1,550	1,950	2,450?	Deg. C.
Comparative volatility in air at 1300° C.[1]		2	60	(1000)	6	1	200	
Specific heat[2]	25.7	26.5			26.2			At 20° C. Joules per gr. atom.
			26.1	25		25	26	0 to 100° C. Joules per gr. atom.
Temperature coefficient of linear expansion	14.2	8.9 11.30	6.5	6.1	11.8	8.4	9.1	× 10-6 at 20° C. × 10-6 at 1000° C.
Hardness, Brinell:								
Cast		50	172		52	139	220	Baby Brinell
Hard	78	97			109			2 mm. ball 120 kg. load
Annealed	35	47			49			
Hardness, Mohs' scale	2.5	4.3	6.5	7.0	4.8		6.5	Diamond = 10
Ultimate strength:								
Hard	26	34			39			Kg/mm.²; 0.5-mm. wire
Annealed		15			14			Kg/mm.²; 0.5-mm. wire
Elongation:								
Hard		0.8			1.0			Per cent. 2 in.; 0.5-mm. wire
Annealed	25	32			24			Per cent. 2 in.; 0.5-mm. wire
Electrical resistance at 0° C., [3]annealed	14.68	60.0	32.1	57.1	64.8	30.7	87.0	Ohms per mil. ft.
Temp. coef. of resistance per ° C.[3]								
Hard		0.003917			0.0037			0–100° C.
Annealed	0.00398	0.003923						0–100° C.
Annealed		0.00318			0.00236			0–1200° C.
E.m.f. against Pt at 1100° C[4]			+14.5		—13.5	+15.8		M. v.

[1] Crookes: *Proc.* Roy. Soc. (1912).
[2] International Critical Tables, I, 104.
[3] Bureau of Standards.
[4] Holborn and Day.
* Taken from a more extensive table in Technical Paper No. 70, A. I. M. E., Carter: "The Platinum Metals and Their Alloys."

by special heat treatment has brougnt to the attention of engineers the importance of accurate furnace temperature control, and no thermocouple material has been found to equal in life and reliability the Le Chatelier couple, consisting of platinum and platinum—10 per cent rhodium. Thermocouple wires can be made of any diameter, but for commercial use experience has shown that the most economical diameter is 0.6 mm. or 0.0236 in.; wires of sizes below this of course cost less, but the life is so much shortened that there is no economy in their use.

Considerable quantities of platinum are used in the form of wire or strip as the resistor of electric furnaces which have to be used above 1,100 deg. C. Although the capital charge is high when platinum is used for this purpose, it has sometimes been found economical to use it, even with furnaces of considerable size. Platinum—10 per cent rhodium is often used for this purpose since it has a higher electrical resistance and lower rate of volatilization and crystallization than platinum.

IN THE explosives industry, 90 platinum—10 iridium, or 80 platinum—20 iridium are used in large quantities as an ignition wire in detonating caps. The uniformity of resistance and permanance causes these alloys to be preferred to all other metals, since dependability is of great importance.

In the manufacture of rayon the liquid is squirted through small cups in the base of which are numerous small holes of exceedingly precise diameter. These cups, or spinnerettes, are generally made of precious metal alloys because it is essential that no metallic impurities be present in rayon such as might easily be introduced by the action of the bath on base-metal spinnerettes. Furthermore, as it is necessary to clean out the holes which become stopped up, it is preferable to be able to use acids for this purpose, and to know that the metal will be unattacked during the operation. Some platinum cups are used, but more generally gold containing up to 30 per cent platinum or palladium is the preferred material.

Although many of the salts of metals of the platinum group are highly colored, the dye industry does not make use of the platinum metals to any extent. Certain ruthenium salts find an application; for example, one ruthenium-ammonium base can be used for dyeing silk or wool purple without a mordant.

Platinum alloy contact points are generally used for "making and breaking" electrical circuits wherever conditions are severe or wherever absolute dependability is required. An alloy composed of 80 platinum—20 iridium is widely used, for example, in magnetos where the service is severe.

Chamber Acid Depends Upon LEAD

By George O. Hiers
National Lead Company, New York

FREQUENTLY one hears the comment that the degree of civilization of a nation varies directly with its sulphuric-acid production. In the manufacture, use and handling of sulphuric acid the use of lead for constructional purposes and equipment is practically indispensable. Lead also has a very widespread application in other chemical industries, as, for instance, phosphoric-acid manufacture, sulphonation and chlorination processes, explosives industries and hydrofluoric-acid handling. Some of the types of chemical equipment made from lead include pipes, flanges, valves, stirrers, agitators, tanks, coils, kettles, stills, pumps, evaporators, drying pans and drums.

For the construction of chemical equipment there are principally two varieties of lead used in the United States —chemical lead and hard lead. To aid both producer and user of chemical lead, the American Society for Testing Materials has tentatively set up the following specifications for such lead: "This lead contains from 0.04 to 0.08 per cent of copper; from 0.005 to 0.015 per cent of silver and carries less than 0.005 per cent bismuth." Hard lead is an alloy of antimony with lead, the antimony varying in content up to 12 per cent.

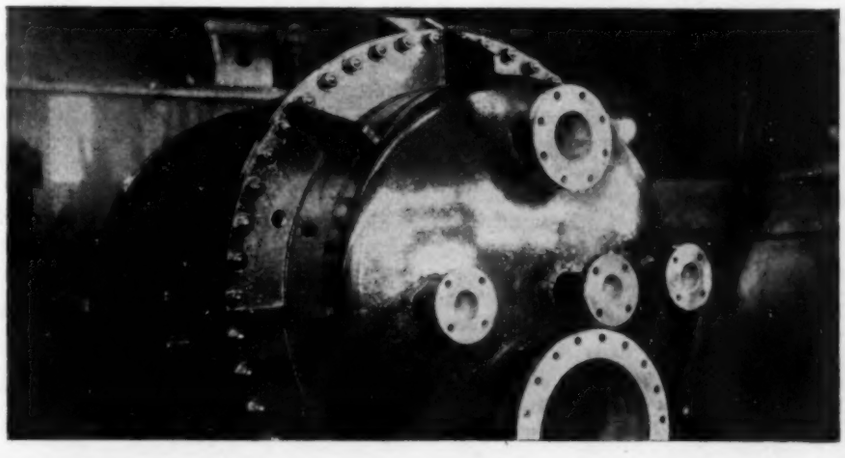
Both of these varieties of lead are manufactured in the forms of sheet and pipe. The sheet is prepared by rolling down cast slabs of metal after it is carefully cleaned. The pipe is produced by an extrusion process sometimes called "squirting."

Lead is noted for its softness and pliability. These properties are applied advantageously in the use of sheet and pipe for constructional purposes. Owing to the fusibility of the metal, the joining of pieces of lead is a simple process, frequently described as autogenous welding or lead burning. The parts to be joined are scraped clean and placed near together, then a clean bar of the same metal is applied with an oxy-gas or oxy-hydrogen flame so that the three parts melt together.

It has been claimed that lead will sustain indefinitely in tension, a load of 415-690 lb. per square inch at ordinary temperature. In calculating the safe working pressure from the bursting strength of lead pipe, it has been found good practice to use an ultimate strength value of 1,740 lb. per square inch and a safety factor of 5. On account of the greater strength of hard lead sheet, this alloy has been used extensively for electrolytic tanks. It is used considerably also in the manufacture of acid pumps, valves and for various castings. Since hard lead is more fusible than chemical lead, the strength of the former barely exceeds that of the latter at 100 deg. C. Consequently there is no advantage to be gained from a mechanical standpoint in using hard lead in preference to chemical lead for apparatus intended for high temperatures.

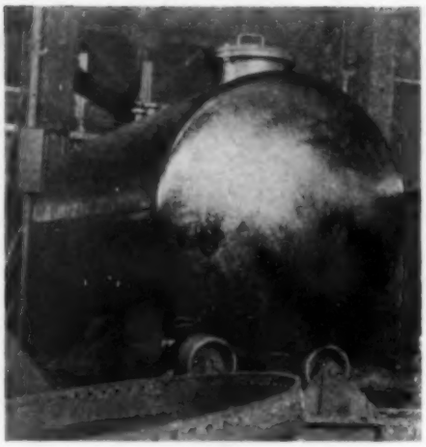
Notable progress has been made in the reinforcement of lead by the use of a stronger metal such as steel. Lead adherent to such a metal is prepared in two practical ways. One method is to bond the two metals together with a thin film of tin or solder. The other method is the so-called "homogeneous" coating

Homogeneous-Lead-Lined Storage Tank, 5 x 10 Ft., ⅛-in. Lining, All Welded



or lining, wherein the lead is attached directly to steel with the aid of careful fluxing. As compared with loose linings or coverings with lead, two distinct advantages, in addition to increased strength, are claimed for the use of reinforced lead, either "bonded" or "homogeneous." One is improvement in heat transfer, and the other, elimination of difficulties due to difference in linear expansion between the lead and the tank or other reinforcing container to which it is attached.

As a result of the development of a special lead anode, there is now an electrolytic zinc on the market of unusually high purity, namely 99.995 per cent zinc. While it had been believed for a long time that to produce the purest electrolytic zinc, lead anodes of the highest purity should be used, this idea was recently shown to be wrong. For the present production of this high grade zinc, anodes made from an alloy containing 98.8 per cent lead, 1.0 per cent silver, and 0.2 per cent arsenic are used. Some years previously, lead-silver anodes had been suggested for the electrolysis of brine.



All-Welded, Homogeneous-Lead-Lined Autoclave

A somewhat new use for lead is in the chromium electroplating industry. Both hard and soft lead are used both for anodes and tank linings.

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ZINC AND ITS ALLOYS *Resist Atmospheric Corrosion*

By William H. Finkeldey

Consulting Engineer, Singmaster & Breyer, New York

ZINC is easily attacked by most common acids, salts and alkalis which prevents its use to any great extent as a material of construction for apparatus and buildings exposed to corrosive chemical fumes. However, there are many plants, generally classed as belonging to the chemical industry, which do not have these extreme corrosion conditions. Where exposure conditions permit its use, zinc, because of its cheapness, offers excellent low-cost corrosion resistance.

The resistance of zinc to corrosion is developed to the greatest extent where the metal is exposed to the weather under ordinary atmosphere conditions. Bright zinc rapidly tarnishes when first exposed, forming a smooth, tightly adherent protective film which apparently is a combination of zinc oxide, zinc carbonate and zinc hydroxide. This film is not readily soluble in ordinary atmospheric waters, nor easily destroyed by other atmospheric agencies. If removed the underlying metal rebuilds the protective film again in a few days' time. However, if the metal is exposed to an atmosphere saturated with water vapor, or immersed in water for long intervals with infrequent drying-out periods, the film grows to greater thickness and becomes soft and less adherent. Its protective value is much reduced.

The rolled metal is considerably used as a roofing and siding material. It is available in the form of flat sheets and long strips in any width up to 20 in. for strips and 60 in. for sheets. The length of strip depends upon the gage, sheets being available in various lengths up to 12 ft. It also may be obtained in the form of corrugated sheets similar in shape and size to the common galvanized-iron sheets. Rolled zinc has its own thickness gage, which is different from the common gages used for other non-ferrous metals and steel. For example No. 10 (0.020 in.) and No. 11 (0.024 in.) are the common roofing thicknesses used with flat sheets or strips. Corrugated sheets ranging in thickness from No. 9 (0.018 in.) to No. 16 (0.045 in.) are more commonly used for roofing and siding of plant buildings. Ordinary commercial zinc sheets in corrugated form are not as strong as galvanized-iron sheets and must be supported at more frequent intervals.

A new stiff zinc alloy called "Zilloy," produced by adding approximately 1 per cent copper and 0.01 per cent magnesium to Prime Western zinc containing certain percentages of lead and cadmium, has been developed and recently patented by the New Jersey Zinc Company. The rolled alloy in the form of corrugated sheets makes an excellent roofing and siding material with a greatly increased resistance to slow flow. This slow flow, or "creep," is a characteristic property of zinc. It is responsible for the sagging experienced in the past with corrugated roofing sheets made from the usual commercial grades where these have been erected on supports spaced for galvanized iron sheets. The increase in tensile strength and stiffness of this alloy over ordinary grades of zinc is shown in Table I.

Table I—Tensile Strength of Zinc and Alloys

	With Grain Lb. per Sq.In.	Across Grain Lb. per Sq.In.
High Grade Zinc	19,000	22,200
Common Prime Western	27,700	40,700
"Zilloy"	44,900	56,500

An indication of the improvement in creep resistance is shown by the fact that the time to produce an elongation of 10 per cent under a load of 10,000 lb. per sq.in. is only 420 minutes for Common Prime Western as compared with 216,000 minutes for Zilloy.

Actual roof loading tests on Zilloy corrugated sheets indicate that they can be placed on the same purlin spacing as ordinary galvanized iron without undue sagging. The corrosion resistance of the new zinc alloy is as good or better than ordinary zinc depending upon the character of the atmosphere.

Zinc is commonly used as a protective coating for iron and steel materials in the form of pipe, sheet, wire, castings and fabricated articles. It is applied by hot-dipping, sherardizing, electrogalvanizing or spraying. The life of the protective coating is dependent upon its thickness and the process used in applying it. In considering the proper type of zinc-coated product to be used for any given service the general rules on the next page may be of assistance.

Table II—Life of Zinc and Zinc Alloys in Years

	Rural	Sea Coast	Semi-Industrial	Heavy Industrial
Commercial rolled zinc sheet or strip 0.020 in. thick	50–75	50	20–30	10–15
Galvanized product 1.25 oz. coating per sq.ft. of surface	30–35	20–25	15–20	8–10
Galvanized product 1.0 oz. per sq.ft. of surface	20–25	15	10–15	6– 8
Galvanized product 0.6 oz. per sq.ft. of surface	8–10	5–8	5	3– 5
Galvanized product 0.2 to 0.3 oz. per sq.ft. of surface	3– 4	2–3	1–2	1

1—For all outdoor and severe indoor service use only materials heavily galvanized by the hot dip process. Sheet and wire products should be purchased under specification to secure heavy enough coatings to give long life. All articles whose manufacture requires severe deformation should be galvanized after fabrication.

2—For semi-protected outdoor and equivalent indoor exposures, sherardized or lightweight hot-dipped coatings are satisfactory. Sherardizing is especially adapted to small castings, fittings, bolts and nuts.

3—For indoor exposures under normal conditions electro-galvanized coatings will be satisfactory. The process is used chiefly to coat small working parts of machines and similar apparatus requiring protection from rusting for their proper mechanical performance.

The thickness of galvanized coatings, usually expressed as ounces per square foot of surface, varies with the character and grade of materials to which the coatings are applied. Sheet and wire products coated by the hot dip process will run from 0.4 oz. to 1.2 oz. per square foot of surface, while structural steel shapes, castings and heavy fabricated articles will carry coatings from 1 to 3 oz. per square foot of surface. Sherardized and electro-galvanized coatings are generally light in weight, 0.1 to 0.5 oz. per square foot of surface, because of the difficulty in applying and the unsatisfactory character of heavier coatings. Sprayed coatings are porous and non-uniform in thickness. Their corrosion resistance is not equal to the same weight of coating applied by the hot dip process.

Coatings of zinc are used to protect certain steel parts of driers, tubs, stirrers, pumps and other apparatus used in the manufacture of lithopone and other high quality white pigments. Since the corrosion products of zinc are all white salts, which do not discolor the white pigments, the use of zinc coatings in such cases is worth while even though their rate of corrosion is much more rapid than with ordinary atmospheric attack.

The life of zinc and zinc-coated products is variable, depending upon the character of the atmosphere in which they are exposed. Table II may be of assistance in selecting the proper thickness of zinc or zinc coatings for given service conditions.

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ELECTRO-DEPOSITED *Films for Resistant Surfaces*

By Colin G. Fink

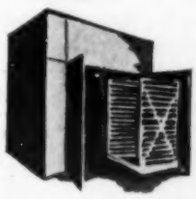
Head, Division of Electrochemistry, Columbia University, New York

LESS than a score of years ago electroplating was largely an art founded on a multitude of formulas, many of them of the mysterious or secret type; today large-scale commercial electroplating is developing into a very exact science. This radical change has been brought about as the result of two rather distinct influences. One, and the more fundamental, is the development of large-scale plating, much of

which is automatic, such as is carried out by the automotive industries. The second influence is the recognition by the university laboratories that electroplating is based on very exact principles. It is the application of laws of physical chemistry to electroplating that has been the main incentive to the researches carried out at the universities in this country and abroad.

Aside from these two influences we must not overlook another very important factor to which may be attributed much of the widespread commercial development of electroplating today. This factor is the change in purpose of electroplating within the last score of years. Whereas electroplating formerly was carried out with the view of improving upon the looks of a base metal —for example, gold-plating or silver-plating nickel-silver—today the chief concern of most of the large plating establishments is how thoroughly the plating will protect the base metal underneath from atmospheric and other corrosion. Yellow brass fittings were once familiar objects on every hand. However, with a decided change in the labor situation, polished brass has become a luxury as compared with brass fittings electroplated with a corrosion-resistant layer of chromium or nickel or other metal or alloy.

Finally, a minor factor that helped to bring about the new era in electroplating is the matter of cost. In combating corrosion and developing corrosion-resistant metals and alloys we have, unfortunately, been confronted with the higher fabricating costs of the corrosion-resistant alloys. On the other hand, the fabricating cost of steel and the most diverse brass fittings has been very appreciably reduced within the last 20 years. And so the electroplater has taken ordinary steel and yellow brass, covered them with a corrosion- and wear-resistant film of metal, and has turned out a product costing but a small part of that manufactured out of our best corrosion-resistant alloys today.



The thickness of the electroplated metal film required to insure the necessary resistance to corrosion varies with different metals, and varies also with the uses to which the finished product is to be put. Very often the film is not more than 0.0002 in. in thickness, and for special purposes it may be as thick as 0.001 in., or about one-third the diameter of the human hair.

To fully appreciate that electroplating is now a part of the science of electrochemistry, we need only visit one of the modern electroplating establishments and there have the superintendent tell us how he regulates the hydrogen-ion concentration of his bath, or why he uses this buffer or that depolarizer. Electrodeposition of nickel is carried out today according to very strict principles. The large plant of the International Nickel Company, where many tons of nickel are electrodeposited daily, has introduced a system of pH determination of the electrolyte at regular intervals, with the result that the quality of the product and the efficiency of the electrolytic bath are controlled to a nicety.

It was not so many years ago that nickel-plating shops would discard many gallons of plating solution when it was found that the solution was not operating properly, and new solutions were made up without any attempt to correct the old. Such practice has been entirely eradicated. We know the exact composition of the bath; we know how to change it if necessary; we know the causes of peeling of nickel and how to correct it; we know the effect of temperature of the bath, the effect of suspended particles, the presence of small amounts of chloride, and other phases of the problem. We know that we add boric acid to the solution as a buffer

and not because it is part of a secret formula; boric acid has a very well-defined effect upon the hydrogen-ion concentration of the solution. We know that the peeling of the nickel is due to the presence of hydrogen and, by largely eliminating the effect of hydrogen through the addition of hydrogen peroxide or sodium perborate, peeling disappears.

One of the most widely used corrosion-protective metals is chromium, applied either directly on brass, steel, or other metals, or with an intervening layer of nickel, or of copper and nickel. Many of the steel automobile bumpers today have a preliminary coat of copper, an intermediate coat of nickel, and a final coat of chromium. Chromium-plated articles have resisted remarkably well both atmospheric corrosion and sea-water corrosion. Many thousands of marine fittings have been chromium-plated and are still as bright today as they were years ago when first put into service.

THERE are two characteristic properties of chromium in which it distinguishes itself from the other metals usually electrodeposited. First is the extreme hardness and erosion resistance of the plate that can be brought about by properly selecting current density, bath composition, and temperature. The second interesting property of chromium is its inertness to sulphur and sulphur compounds. Nickel, zinc, lead, copper, and all of the other metals except the very noble metals platinum and gold, readily combine with sulphur. Stills and cracking units used in the oil industry, in which the inner steel wall is directly exposed to the sulphur in the oil, soon disintegrate. Chromium-plated steel stills, on the other hand, have shown a very prolonged life. In the paper industry chromium plate has been used on tubes for waste sulphate-liquor evaporators and on paper machine rolls, both with excellent results. Finally, the resistance of chromium to organic acids, notably uric acid, should be mentioned.

Second in importance to chromium as a corrosion-resistant plate are the two sister metals, zinc and cadmium. Electrogalvanizing has successfully competed with hot galvanizing and sherardising. One of the advantages of electrogalvanizing is that the steel, brass, or other metal part to which the zinc coating is applied does not lose its temper during the plating operation. Furthermore, hot galvanizing is applicable primarily to steel parts and can be applied to non-ferrous alloys, such as brass, only with difficulty. Cadmium, even though the price of the metal is much above that of its sister, zinc, has found a new field of its own. It retains its luster better than zinc, presents a more attractive appearance, and in many corrosion tests has stood up better than zinc of the same thickness. Cadmium plate is finding an increasingly large field of usefulness. Recently alloys of cadmium and other metals have been electrodeposited, resulting in comparatively hard, wear-resistant films.

Although the electrodeposition of lead is being carried out on a very large scale at various refining plants in this country and in Europe, following the lines originally laid down by Anson G. Betts, lead-plating of brass and steel is carried out to only a limited extent. However, we must not overlook a very important application: the lead-lining, by electrodeposition, of brass shells used in gas warfare.

Electroplating has started on a new phase of its existence. Many of our old ideas have been abandoned. We fully realize today that almost any specified quality of plate can be produced by changing conditions or composition of the bath. Researches within the last few years have revealed that metals heretofore looked upon as impossible to electrodeposit from aqueous solutions can be thus deposited on the basis of our fundamental knowledge of electro- and physical chemistry. We look to the very near future for the introduction into industry of base metal parts protected with metal films resistant not only to atmospheric and seawater corrosion but also to corrosion of the severest kind such as, for example, that of hydrochloric acid, or that of acid ferric chloride solutions. It is gratifying to note the increasing interest in scientific laboratories in the fundamental principles of electroplating, and the growing appreciation of the unlimited possibilities of the new electroplating art in bringing about results heretofore hardly dreamed of.

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STELLITE

For Resistance to Erosion And Abrasion

By W. A. Wissler

Union Carbide & Carbon Corporation, New York

HAYNES STELLITE, a cobalt-chromium-tungsten alloy, has been known as a cutting-tool alloy for many years. Today, due to the development of the Stelliting process, it is finding wide use in a comparatively new field, namely, resistance to wear or abrasion and to combined abrasion and corrosion.

The demand for faster production and longer life for all machine parts subject to abrasion has resulted in the development of the hard-facing process, which consists in welding a surface of a wear-resisting alloy onto an iron or steel base. This process produces a composite article having a surface of highly specialized alloy capable of resisting abrasion, combined with a steel or iron base that has ample strength and toughness to support the wear-resisting surface. Such a composite part has great economic advantage as it will wear much longer than a solid steel or iron part and is much stronger and cheaper than if it were made entirely of the wear-resisting alloy. The process also permits the rebuilding of worn parts, thus extending their life indefinitely.

A HARD-FACING alloy must have great resistance to abrasion. This depends upon various properties, of which the most important is the hardness of the alloy while at the highest local temperature that may be developed when in operation. All operations involving friction generate heat which is concentrated in very thin surface layers and produces local temperatures often 500 deg. C. or higher. Red hardness, which is the hardness measured when the alloy is red hot, gives a reliable indication of the ability of the metal to resist severe abrasion. Red hardness cannot be calculated or predicted from cold hardness but may be measured either in the laboratory or by comparing the life obtained from different alloys when put to use on shop operations involving abrasive wear. It has been found that the highest degree of red hardness is possessed by a non-ferrous alloy of cobalt, chromium, and tungsten. Fortunately, this alloy, Haynes Stellite, can be welded readily by either the oxyacetylene or arc methods, resulting in the process of Stelliting.

While the corrosion-resisting properties of Haynes Stellite also have been known for some time, the comparatively high cost of the alloy has limited its use for this purpose alone, except where the prevention of corrosion is of the utmost importance, as in emergency control mechanism for large steam turbines. Where corrosive action is combined with abrasion, as in the manufacture of dry cells, in the pelleting of certain medicines and in valves for apparatus handling food products, the properties of Haynes Stellite make it very useful.

Haynes Stellite is being extensively used in many of the large industries wherever severe abrasion is encountered. Here are included agricultural machinery, rock drilling and digging equipment, and dies for metal-forming operations. The paint industry uses this alloy on grinding and pulverizing machinery. Cement and cement clinker are both ground and conveyed with the help of Haynes Stellite. The active surfaces of colloid mills are being hard-faced with this alloy, as is grinding and crushing equipment of all kinds.

Where Chemical Engineers Use HARD RUBBER *In the Plant*

By D. E. Jones
Chemist, American Hard Rubber Company, Butler, N. J.

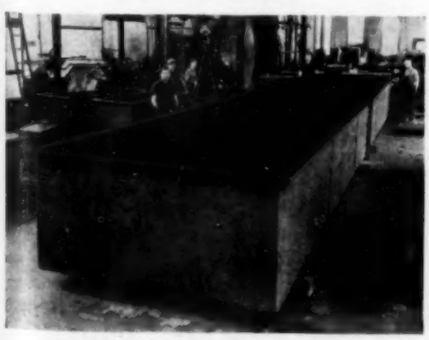
HARD RUBBER as a material of construction is of great importance to the chemical engineer, chiefly because of its corrosion-resisting properties. Few substances can be compared with it considering its wide range of applications.

The difference in composition between hard rubber and soft rubber lies in the sulphur content. Hard rubber contains up to 50 per cent sulphur based on the rubber content. Like soft rubber, it may be compounded with materials other than sulphur for the purpose of changing certain physical properties, such as color, tensile strength, or deformation under heat. This permits the manufacture of articles to meet a great variety of service conditions.

It is impossible, therefore, to tabulate the physical properties of hard rubber except in a general way. For comparison with other materials the following properties may be of interest:

Tensile strength—1,500-10,000 lb. per sq.in.
Elongation—1 per cent upward; as the tensile strength increases the elongation tends to decrease.
Compressive strength—3,000-20,000 lb. per sq.in.
Specific gravity—1.15 upward.
Scleroscopic hardness—35-70.
Dielectric strength—Up to 1,000-1,200 volts per mil.
Resistivity (volume)—Up to 10^{15} ohms cm.

Hard rubber is softened by heat, but by compounding it is possible to make



Hard-Rubber-Lined Pickling Tank Ready for Shipment

grades which can be used up to 200 deg. F. with satisfaction. In addition it is non-porous, non-absorbent, non-hygroscopic and odorless. It may be machined, cut, threaded, sawed or ground. It may be made in the form of sheets, rods and tubes and various molded shapes. It may also be applied as a lining or covering for metal apparatus such as tanks and agitators.

Its chemical resistance is the most important feature of hard rubber for the chemical engineer. Hard rubber is chemically inert to a high degree. It can be used successfully in conjunction with sulphuric acid up to 50 deg. Bé. or nitric acid up to 16 deg. Bé. Hydrochloric acid of any concentration, hydrofluoric, phosphoric and acetic acids, as well as many others, have no effect on hard rubber properly compounded. It is not attacked by caustic soda or potash, or by most metallic salts such as zinc chloride or sulphate, stannous or stannic chloride, ferric chloride, calcium chloride and so on. Corrosive gases such as hydrochloric acid and chlorine are not harmful.

Hard rubber is attacked by such powerful oxidizing solutions as hot, concentrated sulphuric acid and concentrated nitric acid. It is softened and caused to swell by materials such as benzol, chloroform, carbon bisulphide and aniline. It is not recommended for use in handling these substances.

The use of hard-rubber-lined tanks for storing, mixing and processing with corrosive chemicals is increasing. Hard-rubber-lined tanks as long as 60 ft. are now in use. Such tanks are made in sections and assembled at the plant of the customer. Pipe lines, also, with their fittings and valves are lined with hard rubber for use with tank installations. Lining and covering are applied to fans, exhausters and other parts that require protection from chemical corrosion.

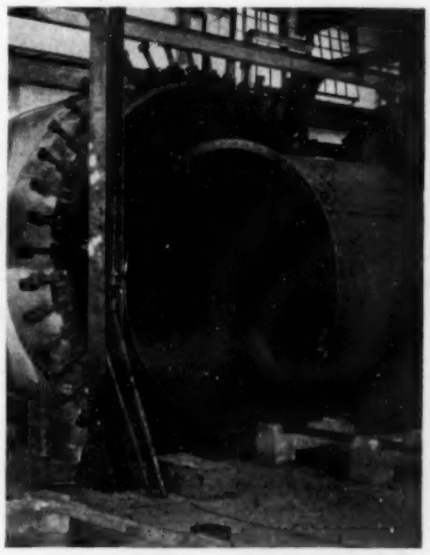
Tanks or vats of hard rubber can also be made, although they are not as rigid as steel tanks, rubber-lined. Tanks up to 15 ft. in length have been made in this way and are giving satisfactory service. In general, the rubber-lined tank is to be preferred on account of its greater strength.

Hard-rubber pipe and fittings are also available for use in connection with the rubber-lined tanks. Pipe ranging in size from ⅛ to 4 in. is regularly supplied and larger sizes can be made if necessary. Fittings such as elbows, tees, unions, flanges, valves, strainers, and ball floats are also available; all have standard pipe threads so that complete conveying lines can be assembled readily.

For circulating corrosive liquids, reciprocating, centrifugal and rotary gear-type pumps can be purchased. These are so made that all parts coming in contact with the liquid are made either from hard rubber or metal covered with rubber. Pumps are available in capacities from 6 to 200 g.p.m.

A complete assortment of utensils, including buckets, dippers, funnels, jars, baskets and scoops, also is available. In other words, a complete installation for handling, storing and conveying corrosive chemicals may be made from hard rubber.

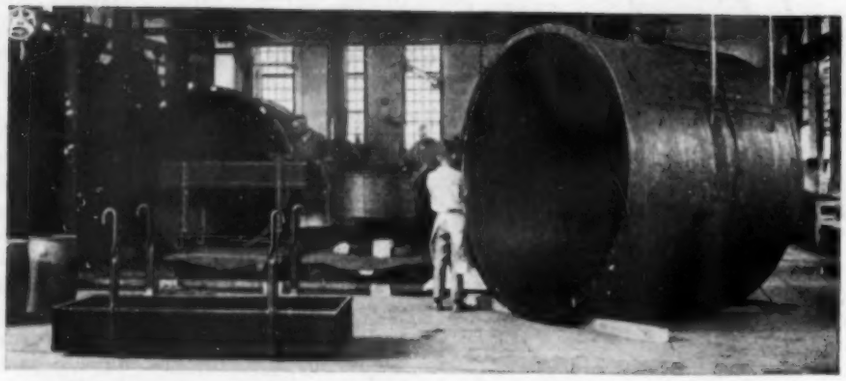
Passing from the general to the specific, a few commercial applications may be of interest. The silk dyeing in-



Large Hard-Rubber-Lined Tank About to Be Placed in the Vulcanizer

dustry uses hard-rubber equipment extensively in handling stannic chloride solution used in weighting the silk. Special applications, such as dipping baskets, dyesticks and centrifugal baskets also are used. Considerable hard rubber is used in rayon manufacture to avoid contamination of the product with impurities such as iron. Hard rubber is used also in various industries where hydrochloric acid must be stored and conveyed. These applications include the extraction of rare metals from their ores, the manufacture of galvanized iron wire, of dyes, and numerous other products.

Hard rubber is useful in handling plating and etching solutions. Hard-rubber goosenecks, electrode separators and tanks are in general use, the tanks also serving to reduce electrical leakage to a minimum. Again, in the manufacture of chlorine and hypochlorites a



Parts Including Dipping Baskets, a Large Tank and a Centrifuge Basket, All in Process of Covering With Hard Rubber

considerable quantity of hard rubber is used. Hard-rubber tanks and drums are used for storing and transporting sodium-hypochlorite bleaching solutions, extensively used in bleaching and laundering.

Many installations of hard-rubber equipment have been made in plants manufacturing food products, such as fruit juices. Its non-porous and non-absorbent properties are of value here in addition to its corrosion-resisting properties.

The above-mentioned uses serve to show the wide range of application of this material in the field of chemical engineering. Outside the field, applications are even more varied, indicating an extremely versatile construction material.

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SOFT RUBBER —

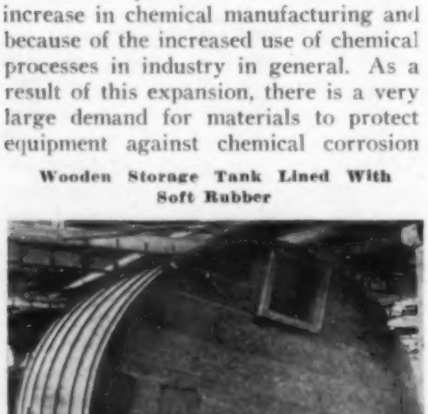
Versatile Lining for Process And Storage Equipment

By N. Gibson Madge

United States Rubber Company, Passaic, N. J.

CHEMISTRY is playing an increasingly important rôle in industry, both because of the increase in chemical manufacturing and because of the increased use of chemical processes in industry in general. As a result of this expansion, there is a very large demand for materials to protect equipment against chemical corrosion and to reduce maintenance and replacement expenses.

Wooden Storage Tank Lined With Soft Rubber



Rubber in its various forms fulfills these requirements through its corrosion- and erosion-resisting properties. It can be readily applied to most types of equipment, either at the rubber factory or at the chemical plant. There is consequently a growing tendency toward the use of rubber to protect chemical equipment against corrosion, not only for the purpose of saving the equipment itself, but to prevent contamination of the product.

The appended list gives a number of corrosive materials, with permissible concentrations, which can be handled in rubber-lined equipment. Further recommendations may be obtained from the various manufacturers of rubber linings. Particularly, care should be taken to follow manufacturers' advice concerning permissible temperatures limits.

Rubber-lined tank cars are now being adopted extensively by several chemical manufacturers who handle large quantities of corrosives unsuited to handling in steel. Advantage is thus taken of a great many reductions in cost of handling. When rubber-lined tank cars are used instead of small and fragile containers, savings may be effected in labor in handling, repairs and maintenance, storage space, freight charges (not only is the weight less, but rates are lower), and in loss of acid and containers through breakage.

Some Materials Handled in Rubber

Hydrobromic acid	Concentrated
Hydrofluoric acid	Concentrated
Hydrofluosilicic acid	Concentrated
Hydrochloric acid	Concentrated
Sulphuric acid	Up to 50 per cent
Sulphurous acid	All concentrations
Acid sodium sulphate	Up to saturation
Caustic soda	Up to saturation
Caustic potash	Up to saturation
Calcium chloride	Up to saturation
Ammonia	All concentrations
Sodium chloride	Up to saturation
Zinc sulphate	Up to saturation
Aluminum sulphate	Up to saturation

Storage tanks, both wood and steel, are also lined with rubber. The liquids are handled through rubber-lined pipes or rubber hose, in combination with rubber-lined pumps, valves and fittings. In this way a decided saving is made in the labor of handling over what it would be if carboys were used. Rubber-lined tanks also obviate the danger of breakage with consequent loss of liquids, damage to equipment and buildings and injury to operators. Storage tanks lined with rubber can be placed outside buildings and, where necessary, underground, thus saving space which would be required if carboys were used. Process tanks and vats can also be lined with rubber when need arises. Pumps, valves and fittings of cast iron or other materials, as well as iron pipe, are lined with rubber.

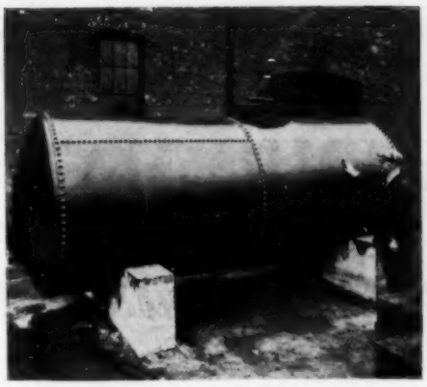
Soft-Rubber Lining is Used in This Metal-Storage Tank

Industries which have equipment that

would be benefited by rubber lining, but which is too large to handle over the railroads may now have linings installed at their own plants. Manufacturers of linings can now accomplish this with apparatus in position, and no more equipment than is usually on hand in any type of plant.

Ventilating systems in plants having corrosion problems, such as those incident to handling HCl fumes, are very successfully protected by rubber lining. The rubber is also applied to the blowers and suction fans and all parts that are exposed to corrosive action. Experience has proved that ventilating systems under acid conditions have given over ten times the life when lined with rubber. Even more severe service, such as is encountered by impellers in agitating equipment, is successfully handled with rubber coverings, frequently increasing the life of parts from days to years.

Rubber as a protective material also can be considered from the angle of avoidance of metallic contamination of the materials handled. Since such contamination is frequently inadmissible, rubber is now being used extensively for this purpose in numerous industries including rayon, dyeing, bleaching and electroplating.



Large Horizontal, Rubber-Lined Storage Tank

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New Importance Attaches to GLASSWARE *as Construction Material*

By A. E. Marshall

Consulting Engineer, New York

A SURVEY of the present-day industrial uses of the special boro-silicate glasses of the type sold under the trade name of Pyrex would have to include all the major industries and many specialized smaller operations, where such glasses perform important functions.

A list of general industrial applications, while out of place in an issue devoted to materials of construction, would definitely prove that these newer types of glass have changed the age-old conception of glass as essentially a transparent, fragile material with a distinctly limited field of application, and substituted the idea of glass as an equipment material, possessing some unique and inherent properties, with transparency sometimes of useful, but usually of incidental, value.

The combination of chemical stability, low coefficient of expansion, relatively high softening temperature and improved surface hardness characterizes this equipment, and its place in the chemical industry can partially be defined by the statement that it permits the direct translation of laboratory operations carried out in glass, to full-scale production, without the introduction of new and difficult problems in securing corrosion-proof apparatus.

The ease with which glass can be fabricated into tubes, and the unexpected high heat-transfer value (40 per cent of that of clear copper) have resulted in an extensive development of equipment using tube forms, such as piping, condensers, coolers and heat interchangers, assembled with flanged, socket or rubber-sleeve joints. Many of the operating coolers and condensers use 16-ft. tube lengths in 2- and 3-in. bores, the lengths being limited by considerations of safe transportation rather than production.

The tubular ware of this type has a distinct advantage over metal for heat exchange work in that the perfection of the surfaces and resistance to corrosion tend to stabilize heat transfer at its initial value, whereas the transfer value of metal tubes rapidly decreases whenever conditions favor the development of interior or exterior coating on the tube walls.

Beverage and food-product plants interested in the preservation of delicate flavors are now turning to the use of flanged-joint pipe lines of boro-silicate glass, and in an entirely different field, but for similar reasons, manufacturers of antitoxins, serums and low-stability chemicals in liquid form are packaging their products in ampoules, bottles and larger containers formed from this material.

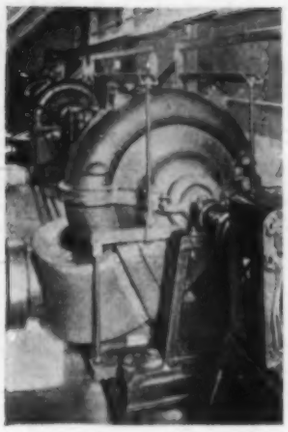
Considerable progress has been made in increasing the size of shapes made by the pressing process, one of the recent interesting developments being the 24-in. tower-column plate described by A. A. Backhaus in the July, 1929, issue of *Chem. & Met.*

It is expected that factory research, now under way, will ultimately result in the production of an all-glass column, and here transparency will be of real value. The simultaneous observation of the functioning of all the plates in a full-size column may well result in the discovery of some new factor which has escaped detection in sight-glass-fitted columns and is not present in small model glass columns.

Radio enthusiasts are familiar with some of the astonishing results secured through the use of Pyrex radio insulators, as for instance the two-way communication between New York and Commander Byrd in the Antarctic, and the picking up by a Philadelphia amateur operator of the "Graf Zeppelin" radio messages while the dirigible was 800 miles east of Tokyo. The electrochemical plant engineer, however, may not be aware of the growing use by the public utilities of boro-silicate power-line insulators for sections of transmitting lines adjacent to chemical plants. The reason is the maintained high insulating value in presence of corrosive dusts and gases. Transmitting problems within the plant might well be reduced by adopting the same means.

The reference in the early part of this article to surface hardness and its practical application can be best illustrated by the use of this glass for godet wheels, filament and thread guides, and dyeing machine reels in the rayon industry. Here surface hardness and resistance to chemical attack both play their part. Further advantage is the homogeneity of non-crystalline glass, made by fusion at high temperatures, and having a body which can be said to be "surface throughout."

The engineer who can forget the general conception of glass and its limitations, and realize that there is available in a wide variety of shapes, a new type of glass with a new combination of properties, will find some real value in studying these special glasses from the standpoint of available commercial materials of construction. Some few of its properties become apparent from a study of Chart (C) in the editorial supplement.



Stoneware Exhaust Fans

Wide Variety of CERAMIC MATERIALS *Find Industrial Application*

By George H. Brown

Director, Department of Ceramics, Rutgers University, New Brunswick, N. J.

CHEMICAL engineering bears an interesting and reciprocal relation to the ceramic industry. Many chemical-engineering processes and materials are used in ceramic manufacture, and in turn many ceramic products find wide application in meeting the diverse requirements of the process industries. Once the term "ceramics" embraced only the clay-working industry—brick, terra cotta, fire-clay refractories, stoneware and porcelain. Today the ceramic field has so broadened that by general acceptance it includes such diverse materials as glass and enameled metals, lime, cement and plasters, gypsum and such special refractories as those from chromite, magnesite, bauxite, mullite and zirconia. In addition, there is a host of mineral materials such as flint, feldspar, mullite, pyrophillite, talc, fullers earth, asbestos, steatite and soapstone that are themselves recognized as ceramic products.

Since this review, however, deals only with materials of construction for chemical engineering equipment, the discussion is limited to a relatively small section of the ceramic industry. Furthermore, glass and acid-resistant brick and cement appear elsewhere.

Of the ceramic materials of construction with which the chemical engineer comes into contact, Prof. A. E. Greaves-Walker has listed the following with the qualities which the user generally considers most important:

1—Chemical stoneware.
- (a) Resistance to chemical action.
- (b) Resistance to mechanical shock.
- (c) Resistance to thermal shock.

2—Acid-proof brick, rings and tower packings.
- (a) Vitrification of porosity.
- (b) Resistance to acid erosion through solution.

3—Acid-resisting cements.
- (a) Resistance to chemical action through wide range of temperatures.

4—Concrete construction.
- (a) Very low porosity.
- (b) Resistance to acid erosion through solution.
- (c) Resistance to mechanical shock.

5—Refractories.
- (a) Resistance to high temperatures.
- (b) Resistance to chemical action at high temperatures principally through solution.

No attempt is made in the present issue to deal in a comprehensive way with refractories, but it is perhaps worth while to point out that the range of use in process industries is so wide as to make specifications practically impossible. In one plant a furnace lining may be subjected to high temperature only, while in another, such as in manufacturing fused anhydrous salts, the temperature is of little importance, but the chemical action is so intense that even high-grade firebrick will last only a short time. In such cases the chemical composition of the refractories and the density are the governing factors.

Chemical Stoneware Improves in Quality and Application

BECAUSE of its resistance to extremely corrosive substances such as aqueous chlorine and hydrochloric acid, which attack most metals, chemical stoneware is one of the most valuable materials of construction used in the chemical industry. Its relatively low cost of production and the facility with which it can be formed into comparatively large shapes of intricate design, make it one of the most universally used materials.

Percy C. Kingsbury, in a recent address before the Rhode Island Section of the American Chemical Society, has shown very clearly how the results of research have improved the quality and characteristics of chemical stoneware. He cited comparisons (Table I) of the physical properties of the ware of today with that made only eight years ago:

Chemical stoneware, as Mr. Kingsbury points out, resembles porcelain but is made from clay bodies having greater plasticity, less shrinkage, a lower temperature of vitrification and much higher mechanical strength before firing. Careful control of shrinkage has made it possible for the manufacturers to effect the perfect fitting of parts required for many chemical applications. Furthermore, on account of the uniform texture of the material, it can be readily machined and polished, and this feature makes it possible to manufacture a wide variety of machinery for handling corrosive products. Exhaust fans and blowers are made that are capable of handling as much as 6,000 cu.ft. per minute of corrosive fumes such as those containing chlorine, sulphur dioxide, hydrochloric acid or hydrogen sulphide. Stoneware pump of a capacity of 1,000 gal. per minute or more are available for handling nitric, phosphoric, muriatic, sulphuric, sulphurous, arsenic, acetic and other acids, as well as solutions of chlorinated brine, sodium hypochlorite and tin tetrachloride. Pebble mills having a capacity of 250 gal. are widely used for grinding drugs, and various chemical and pharmaceutical products in which contamination from metals would have a deleterious effect on quality. It is apparent, therefore, that the stoneware industry is making substantial progress in supplying the severe-service requirements of the chemical industry.

Standardization Increases Use of Enameled Iron and Steel

INCREASINGLY wide application of enameled ware in the chemical-engineering field has resulted from consistent improvement in the quality and acid resistance of the enamel available, and from the co-operative effort on the part of chemical manufacturers in encouraging the acceptance of standardization in design whereby stills, reaction kettles and open and closed evaporators can be built up from standard parts. This standardization movement, which Emerson P. Poste first discussed in *Chem. & Met.* in the issue of November 22, 1922, was further urged by Edward G. Miner

in the issue of April 16, 1923. It has had a favorable effect in lowering both the first cost and the maintenance cost of the equipment. Because of interchangeable parts such as spare liners, the user has been assured of uninterrupted production.

Enamels of proper composition have a thermal expansion so related to that of the metal beneath that the two can withstand any reasonable temperature change without setting up strain and resultant rupture of the enamel. Thus for any temperatures such as may be obtained by indirect heating by steam or oil, enameled equipment has proved satisfactory for handling such extremely corrosive materials as the following acids in either concentrated or dilute form: Hydrochloric, nitric, sulphuric, C. P. phosphoric, hydrobromic, hydriodic as well as a wide range of organic acids. Hydrofluoric acid, since it attacks all glass, cannot be handled in glass-lined equipment, nor is it advisable to use the equipment for alkalis (with the exception of ammonium hydroxide), although there are instances where caustic soda of strength under 5 per cent is being satisfactorily handled in enameled equipment. Sodium and potassium carbonates, although alkaline, have also been handled safely over a wide range of concentrations.

The rate of heat transfer for enameled steel equipment varies between wide limits, since it is a combination of metal and enamel, both of which vary in thickness in different types of apparatus. E. P. Poste, in the article previously cited, indicates the range from one-fifth to one-third that of copper of the same thickness and under the same conditions of temperature difference, velocity, etc.

Some of the severe-service applications of this type of equipment reported by the manufacturers are in the handling of boiling hydrochloric acid in several rubber plants, and of sulphur chloride in a factory manufacturing rubber supplies. Another installation which has been in service for three years involves the making of ethyl chloride with hydrochloric acid under 40-lb. working pressure.

Fused Silica Combines Thermal and Corrosion Resistance

PROPERTIES of fused silica which make it useful in chemical-plant construction are stability to prolonged heat, very low coefficient of expansion, resistance to nearly all acids (commercial phosphoric and hydrofluoric acids being exceptions) and light weight. Pure fused silica has a melting point of 1,750 deg. C. and while it softens slightly at 1,400 deg. C. it does not reach a fluid state until 2,000 deg. C. It is generally recommended for service up to 1,100 deg. C. The coefficient of expansion over the range of 0 to 1,000 deg. C. is 0.00000054 per deg. C.

Table I—Comparison of Physical Properties of Chemical Stoneware

	1921	1928
Ultimate compressive strength, lb. per sq.in.	65,000	113,000
Ultimate tensile strength, lb. per sq.in.	1,500	4,200
Modulus of elasticity, lb. per sq.in.	$8x10^6$	$5.9x10^6$
Thermal conductivity (B.t.u.)	0.81	2.05
Specific heat	0.188	0.199
Linear expansion per 1 deg. F.	$2.7x10^6$	$1.95x10^6$
Comparative Results of Certain Empirical Tests		
Ultimate bending strength	525	1,355
Ultimate torsional strength	298	327
Hardness (ball pressure)	800	1,007
Resistance to impact (swinging hammer)	1.5	4.7
Toughness (loss of weight in tumbling barrel)	6.5	2.6
Resistance to abrasion (loss of weight under sand blast)	5.0	2.0

One of the earliest uses for fused silica—in cascade type concentrator basins in sulphuric acid manufacture—is still among the leading applications. Sulphuric acid manufacture is now tending toward tower concentration, but the fused silica cascade concentrator is still required for making 66 deg. acid of high purity. Extensive use of fused silica apparatus is also found in plants for making hydrochloric and nitric acids.

W. W. Winship in *Canadian Chemistry and Metallurgy*, July, 1929, pp. 285-87, reports the use of silica scrap as a catalyst support, and in making ceramic ware and refractories. The high electrical resistance and thermal properties make it a valuable material in resistance heaters, mercury switches and other electrical apparatus. Transparency to ultra-violet light is another property which has increased its use in mercury vapor lamps which are finding important application in the irradiation of food to increase their vitamin potency.

Diatomaceous Silica Used for Fused Silica Combines Thermal

ALTHOUGH generally used alone for purposes of insulation and filtration, it is in the form of incorporated powders and granules that diatomaceous earth is of interest to the chemical plant as a material of construction. Its high silica content, made available through the large surface area of the material, its light weight, and its resistance to high temperatures (up to 2,000 deg. F.) suit it eminently as a filler for concrete. In this application, it not only improves the workability but also greatly adds to the waterproofing and corrosion-resistant qualities, so that city filtration plants, such as the one at Spartanburg, S. C., and sewage disposal plants, as at Flint, Mich., find its addition to concrete beneficial. Its further uses in protective materials, where the properties named above appear to advantage, are as filler for paints, enamels and various plastic compounds, and in connection with such varied materials as gypsum, magnesite and asbestos.

Asbestos Compounded to Meet Diverse Requirements

FIBROUS ASBESTOS with its unique properties and workability has lent itself as an important constituent of numerous resistant materials. Its adaptability to insulating uses has naturally been the starting point in the development of such typical commercial products as those briefly tabulated on the editorial supplement to this issue.

The materials embodying portland cement as another constituent are intended for use in contact with industrial gases, fumes and liquids where strong acids are absent. Piping made from similar composition finds applications in soil pipe, ducts, flues and stacks for temperatures up to 600 deg. F. The sheet and corrugated forms are intended as resistant casings, partitions, walls, baffles, etc., and wherever else surface is exposed to heat and fumes.

With the addition of high-temperature clay to the asbestos and portland cement, the product assumes greater importance for high-temperature conditions. Resistant up to 1,200 deg. F. and of high mechanical strength, it finds application in heating units, ovens and for similar purposes where its normal avidity for water absorption is not a factor. Asbestos compound with organic binders of various sorts (in addition to portland cement in some products) is intended for insulating and electrical purposes where an incidental resistance to numerous chemical reagents is needed.

EDITOR'S NOTE: *As mentioned editorially in the January, 1929, issue of* CHEM. & MET., *an important corrosion problem in connection with the handling of corrosive sulphur and chlorine compounds in petroleum refining has been solved by the research laboratory of the Universal Oil Products Company through the development of a ceramic lining consisting of furnace cement, white silica foundry sand, sodium silicate and asbestos. This is sprayed on under pressure with a cement gun forming a layer $\frac{1}{8}$ to $\frac{1}{4}$ in. in thickness.*

An illustrated article including field directions for the mixture of batches and their application has been prepared by J. C. Morrell and W. F. Faragher, and will be published in a subsequent number of CHEM. & MET.

Special Treatments Increase Resistance of

PORTLAND CEMENT CONCRETE

By S. R. Mitchell

Consulting Engineer, Los Angeles, Calif.

IN CONSIDERING cement for most construction work, portland cement usually is referred to as the basic material. This may be used with or without special treatment to fit the particular application. For ordinary construction of foundations, piers, footings, reinforced-concrete buildings, pavements, storm drains, sewage pipes, and other miscellaneous uses under ordinary conditions, regular portland cement may be successfully used. However, when the construction includes flood-control dams, water-supply reservoirs, aqueducts, storage tanks in the manufacture of chemicals, perishable foodstuffs and other more or less corrosive commodities, such as animal and vegetable oils or syrups, special-strength cement or treatment of the cement may be necessary before mixing with sand, rock and water to produce the concrete structure. Or in some cases, special treatment of the finished concrete may produce the most satisfactory resistance to corrosion.

REGARDLESS of where cement is to be used buyers should know it has been manufactured to pass the specifications of the A.S.T.M. and the U. S. Bureau of Standards. These call for reasonably safe strength tests, setting-time periods, fineness, soundness, and chemical-constituent limitations. The user should be certain, however, that the cement has not been held several months in storage nor unduly exposed to dampness.

For special use, the highest type of portland cement available should be sought. There are certain severe conditions where it is necessary to use the highest type of portland cement, along with the best grade of sand and rock, in addition to special treatment of the concrete by an admix or coating or by means of the fluatation process with silicates or fluosilicates. Other conditions may call for the use of a cement entirely different from portland cement because of its lack of hydraulic properties. Such cement is used in a mortar to construct brick towers and for sulphuric-acid chambers and arches.

In any portland cement work, the cardinal principles for its proper use must be followed. When special corrosion-resistant material is desired, the special treatment given the cement or concrete may fail if the cement or concrete is carelessly handled. This may come about from improper amount of water, wrong mix proportion and quality, careless curing, old or poorly manufactured cement, silt-coated sand or rock, organic matter in the aggregate, extreme atmospheric heat or cold when mixing, too much heat in the water, cement, sand or rock, improper preparation of sub-base, wrong kind of mixing water, undermixing of the concrete and too much fine sand.

MOST of the severe corrosion of mortars, stucco, and concrete work may be attributed to improper materials or workmanship. Too much water in the mix or overtroweling of the finish will produce soft laitance, inviting weathering corrosion which may have started after abrasion of the soft surface, thus exposing a porous field for attack. Weathering corrosion may proceed slowly or rapidly, depending upon the character of the atmospheric gases, the humidity, temperature changes, amount of rain and wind.

There are a few cases of predetermined high-alkali soil or water conditions where the question arises regarding the advisability of using cement drain tile. A study of such conditions usually is made by the tile concerns, who would not care to recommend their product for any installations where they doubted its ability to resist corrosion. Conditions of cement and concrete-pipe manufacture have considerably improved during the past few years, and extreme density is now obtained, thus cutting the former absorption figure down from 8 per cent to 3 per cent. This alone will improve the corrosion resistance 50 per cent.

In Bulletin 214, U. S. Bureau of Standards, on the durability of cement drain tile in alkali, it is suggested that an alkali soil with 0.10 per cent salts of the sulphate type should call for a study of the subsurface conditions prior to an installation. Again we find results of an alkali survey on the Pacific Coast, where sanitary sewer pipe in good condition has been in contact for several years with high-alkali ground water containing 33,720 parts per million of the sulphate radical SO_4, or a concentration of 3.4 per cent. The explanation of this will reveal the fact that, on account of pipe density, proper installation and impervious soil covering, there was no opportunity for the alkali salts to crystallize within the pores of the concrete and rupture it by expansion.

Portland cement used in plain or reinforced concrete piling, piers and other structures, in or near sea water, has been much investigated to determine the reasons for certain failures along with other successful installations. Results have shown that corrosion has been caused mostly above high water mark by surface evaporation, concentration and crystallization within a porous concrete. Crystals of calcium sulphate and magnesium hydroxide have resulted from reaction within the pores between calcium hydroxide crystals (formed in the hydration of cement) and the alkali sulphate and magnesium salts of the sea water. The volume of the insoluble reaction products is much greater than the calcium hydroxide crystals replaced and these products cause a disruptive force resulting in surface spalling.

It has been determined that a well-cured (60 days), rich concrete mixture (1-1-2), containing a high type portland cement, a coarse washed sand containing only a trace of minus 100 mesh material, molded with as dry a workable consistency as possible, will give satisfactory results in sea water. Reinforcing rods should be covered at least 3 in. to prevent contact with the water. To prevent corrosion of reinforcing rods, it is suggested that they be painted with a grout of 90 per cent portland cement and 10 per cent zinc yellow (a chromate paint pigment which showed the greatest rust-inhibiting power in Cushman's experiments). This is recommended provided brief preliminary experiments have shown that the rod coating will not interfere with its bond to the surrounding concrete.

ABERTHAW piling tests in the Charleston Navy Yard indicated that crude oil floating on the water has coated certain piles at the water line, and apparently sealed off the concrete and prevented further corrosion which had begun during the first few years of exposure.

Protection of cement mixtures from attack by strong mineral or organic acids is a difficult and highly specialized

job and usually costly. One form of protection is the fluatation process, which includes the successive application of several coats of water-soluble fluosilicates to dry, cured cement or concrete work, with 24-hour periods between coats. Sodium, potassium, magnesium, aluminum, lead and zinc fluosilicates are used.

Any one of these treatments will toughen or harden a soft cement topping when carefully applied and render it more corrosion resistant. A satisfactory treatment is the combination of two coats of cold magnesium fluosilicate solution, one part by weight of crystals to three of hot water in a wooden vessel, followed, at 24-hour intervals, between coats, with a heavy coat of lead fluosilicate (solution of 2.0 sp. gr. diluted with three volumes of cold water). This is recommended for effective resistance to alkalis or weak acids. A phenol-formaldehyde resin is recommended by the German Concrete Association to be painted on concrete for acid-resistance. Baking is necessary for this treatment, which must be a perfect heavy coating to be effective.

Molten sulphur or sulphur and sand have been used with success on concrete. It is much strengthened and made quite corrosion-resistant when properly treated. The method of application is rather difficult on account of the molten mixture. If not properly applied, a brittle coating is produced and on account of this condition vibrations may cause cracking. Sulphur treatments may be limited in their scope on account of fire hazard.

IN the corrosion of portland cement, calcium hydroxide crystals formed in the hydration process, together with hydrated tri-calcium aluminate, monocrystalline hydrated calcium silicate, compounds of magnesium, iron and alkalis, seem to be the most readily attacked by alkalis or acids.

Puzzolanic silicates have been found to be quite effective as admixes in portland-cement concretes to combine with the excess of calcium hydroxide while moist. This combination prevents leaching of the lime and produces additional cementing compounds of calcium and aluminum silicates within the mass which assist in holding down the hydration temperatures. In addition it strengthens the concrete, has a tendency to prevent cracking and promotes resistance to alkali corrosion. Admixtures of as much as 20 per cent of the volume of cement may be used, provided the admix is all active aluminum silicates. Pumicite and trass are used for the above and may be found in many countries.

Professor H. K. Benson, of the University of Washington, has found that a treatment of concrete with a 6 per cent admix, plus a coating of a bituminous preparation, has given good results in acid-proofing. A practical corrosion-resistant admix of water-emulsified asphaltum is now coming into extensive use on both the East and West coasts. It is readily mixed with the wet concrete in proportions varying from 10 per cent of the weight of the cement up to 50 per cent or more, depending upon the particular application. When cured, the concrete contains a more or less plastic void-filler which then aids in its corrosion resistance.

Asphaltic and coal tar, as well as vegetable and animal pitches, have been used with success on concrete tanks for acid resistance and applied to concrete structures for dampproofing. The main trouble has been the proper bonding, and for this it seems almost necessary to use a cutback thin primer solution of the same material as the finish coat. Specifications for such coatings have been prepared by the A.S.T.M. and U. S. Bureau of Standards.

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Chemical BRICK AND CEMENT *Afford Long-Time Protection*

By A. M. Webb

Secretary, Chemical Construction Company, Charlotte, N. C.

APPLICATION of chemical brick and acid-proof cement, otherwise termed "acid-proof masonry," is best made either for solid masonry towers and similar apparatus, in lieu of acid-resisting metals, or for the additional protection of acid-resisting metal casings. In the first case the walls are constructed of solid masonry having no outer or inner lining; and in the second case an acid-resisting metal casing is lined with masonry work, principally for the purpose of preventing corrosion—especially when hot acids are encountered—and, further, to protect the casing against mechanical wear and abrasion.

In the manufacture of strong sulphuric acid by the contact process, steel and iron are used almost exclusively, except that in most cases the steel towers and tanks are lined with acid-proof masonry for the purpose of prolonging the life of the steel shells. In the manufacture of weaker acid by the chamber process, Gay Lussac and Glover towers very often are constructed with solid masonry walls having only a lead pan at the bottom. This lead pan is heavily lined with acid-proof masonry in order to prolong its life.

In the concentration of sulphuric acid, iron and lead pans and similar apparatus, formerly used for the concentration, have proved expensive and unserviceable. Today the recognized construction is to build that part of the concentrating unit containing the hot acid baths of a steel shell containing a layer of lead and then a heavy lining of acid-proof masonry. In this way the lead is protected both from the hot acid and abrasion, and the steel shell serves only as a mechanical casing.

Construction as described above has been found economical and durable, and in most instances the original apparatus that was erected about the time that acid-proof masonry was first introduced commercially into the United States is still standing and in use, showing very little depreciation.

The durability of acid-proof masonry is not known. It appeared in this country, on a commercial scale, about 18 years ago. In some cases it has been a success and in others, a failure. In practically all cases failures have been traced back to a chemical brick of poor quality.

Most of the chemical brick produced in this country is made from shale thoroughly vitrified. Good brick requires a shale finely ground, free from certain impurities, and burned to a thorough vitrification. In a great many shale deposits of the country there are certain objectionable ingredients which make it impossible to produce a good chemical brick. A first-class acid-resisting shale is found in only a few localities. There has never been a standard analysis adopted for chemical brick. The best way to select a good brand is either by comparative laboratory test or by the reputation and long usage of the brick.

In the manufacture and use of nitric and muriatic acids white silica brick has found favor. Prior to the

perfection of chrome iron for absorption towers and similar equipment for nitric-acid plants, such apparatus was constructed of acid-proof masonry. In some of the recent plants using chrome iron for the towers, these have been lined with acid-proof masonry in order to prolong the life of the metal. The long life and smaller first cost of the towers will still make them preferable in many cases.

Acid-proof cement used as a binder for the chemical brick must be mechanically strong as well as acid-resisting. If the cement is properly ground and blended and does not contain an appreciable amount of impurities that give way in the presence of acid, the durability will be great and the mechanical strength will exceed that of portland cement. This means that acid-proof masonry has considerably more mechanical strength than ordinary masonry.

Towers used for absorption, oxidation and cooling of acid gases require in most cases packing materials. Rings, bricks and special blocks made from shale and other acid-resisting ceramic materials are used almost exclusively. As different acids of various strengths and temperatures will be encountered, the packing materials must be selected accordingly. Bricks and rings made from acid-proof shale, and thoroughly vitrified, are used in most cases. Mechanical strength, as well as durability, also is required, as the packing should be self-supporting in all cases and the same care must be exercised in selecting packing materials as when selecting chemical brick.

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New Construction Possibilities in GLASS-ENAMELED TUBING

By S. J. Crooker
The Babcock & Wilcox Company, New York

SECURING a material of construction, in the form of pipe or tubing, successfully to resist the action of boiling sulphuric acid of all concentrations, is a problem which has for some time faced the Babcock & Wilcox Company. In connection with the boiler operation of power plants, rapid corrosion occurs on the economizer units. This results from precipitation on the economizer tubes of sulphuric acid formed from the sulphur in the fuel used. High-sulphur coal is the chief source of trouble in this respect.

Steel tubes in the economizer side of boilers fail rapidly from acid corrosion where the temperatures are suitable for precipitation of the sulphur compounds. The chief source of corrosion is from concentrated sulphuric acid because of the temperatures encountered in the economizer end of the boiler. However, absorption of water when the units are down, and frequent washings to remove soot, cause dilution of the acid, so that actually all concentrations of acid are present.

Such metallic materials as are available in tubular form do not offer sufficient resistance to this attack to combat successfully the corrosive conditions encountered. Hence a survey of other corrosion-resistant metallic materials was made, and aside from some of the rare metals, no commercially available metal or alloy seemed to offer the required resistance to sulphuric acid at temperatures of 300 to 500 deg. F. Laboratory and service tests bore out this conclusion.

After considerable study of the problem in 1925, the Babcock & Wilcox Tube Company developed a process for vitreous-enameling the external surfaces of tubes in long lengths. Enamels were selected which offered extreme resistance to mineral-acid attack and service tests in economizers proved the value of such material. Laboratory tests showed that chemical attack was negligible in boiling sulphuric acid at temperatures up to 550 deg. F.

The effect of quenching hot enameled surfaces with water was studied to determine whether cracking would occur in service on sudden cooling. Repeated quenching of enameled tubes from temperatures of 300 to 600 deg. F. showed no tendency for the enamel to crack or craze with quenchings repeated up to 1,800 times.

The enamel used, supplied by the Glascote Company, has been developed especially for severely corrosive conditions and is entirely resistant to mineral acids such as hydrochloric, sulphuric and nitric in all concentrations. It is suitable for organic acids such as acetic and citric acid and for corrosive salt solutions. Being a silicate glass, it is readily attacked by hydrofluoric acid, fluorine or caustic alkalis.

Because of the inherent difficulty in handling glass-coated steel pipe, this material is recommended particularly for applications in hydrochloric and sulphuric acid solutions, while chromium irons such as Enduro "A," and chromium-nickel irons, such as Enduro KA2, are suggested for nitric acid work.

IT will be recognized that glass-enameled pipe offers objectionable features in that it is liable to injury from mechanical shock. Hence, an extremely important feature connected with the successful application of enameled pipe lies in the development of a portable repairing outfit for patching any spot or defect which might occur in transit or in service. Repairing consists of suitably preparing the surface at and around the defect, applying milled enamel and fusing the patch by means of a hinged electric resistance furnace placed around the section of pipe containing the defect.

Tubing and pipe will be available, coated externally with vitreous enamel, in ordinary commercial lengths and in diameters up to 5 in. pipe size. Tubes can be produced practically straight and it is possible that coils and bent sections can be supplied. Enameled steel tube sheets or baffles, with rubber-gasket joints or threaded ends and corrosion-resistant fittings, will be used in construction of enameled equipment for evaporators, heaters, coolers, digesters, acid concentrators and so on. Each application is an individual problem so that details of construction cannot be given here.

Careful experiments on the heat transfer rate of externally enameled steel tubing indicated that the transfer difference, as compared to ordinary steel, was not sufficient to interfere with its use in many forms of equipment where this property is of importance. The thermal expansion of the enamel used is very close to that of the steel, so that no difficulty arises when using the coated material at temperatures up to 600 deg. F. Vibration does not seriously affect the enamel coating, unless stress above the elastic limit of the steel base be applied. Vibration tests on 20-ft. tube lengths were made in which both ends of the tube were anchored and a rapid up-and-down flexure of the section was given by an oscillating cam attached to the center of the tube. Repetition of the test to 1,000,000 flexures showed no cracking or flaking of the enamel.

Resistant WOODS *Satisfy Most Corrosion Requirements*

ALTHOUGH it is recognized that laboratory tests of wood cannot hope to duplicate the strain and rough treatment which a wooden tank may be expected to receive in actual use, such tests have undoubted value and have been shown in practice to yield reliable data. With these limitations in mind, and in order to assist in making recommendations concerning proper woods for tank materials, the Hauser-Stander Tank Company undertook to investigate the effect upon six woods most commonly used for tanks, of water and 16 different corrosive agents, in various concentrations.

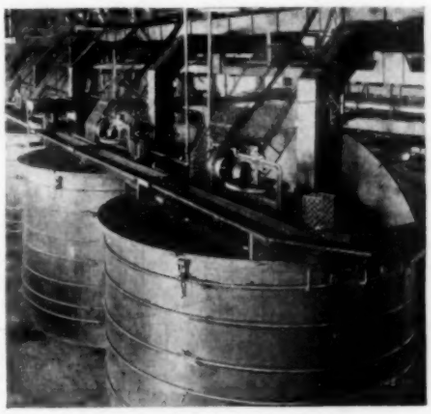
The solutions tested included the following:

Water
Acetic acid: 5, 25, 50 per cent and glacial.
Hydrochloric acid: 5, 10, 25, 50 per cent and concentrated.
Sulphuric acid: 1, 5, 10, 25 per cent.
Nitric acid: 5, 10, 25 per cent.
Sodium hydroxide: 1, 5, 10, 25 per cent.
Sodium sulphide: 5, 20 per cent.
Sodium bi-sulphite: 10, 25 per cent.
Sodium carbonate: 5, 20 per cent.
Calcium hydroxide: filtered; 10 per cent suspension.
Bleaching powder ($Ca(OCl)_2$): filtered; 10 per cent suspension.
Sodium chloride: 10, 25 per cent.
Calcium chloride: 10, 25 per cent.
Turpentine.
Linseed oil.
Cottonseed oil fatty acids.

The woods used were: Red Gulf cypress, Douglas fir, long leaf yellow pine, California redwood, hard maple, and white oak. Test strips 4x1x¼-in. having a volume of 1 cu.in. were used in every case. In addition to investigation of the effect upon the various woods, observations were recorded as to the superficial action of the woods upon the corrosives. That is, while analyses of the impurities gained by the solutions were not made, coloring matter was noted and in the case of water, taste was also observed.

Procedure included measurement of the weight of solution absorbed by the samples under various conditions, together with careful measurement of expansion or shrinkage. In addition, other characteristics such as softness, brittleness, warping and disintegration were observed and recorded.

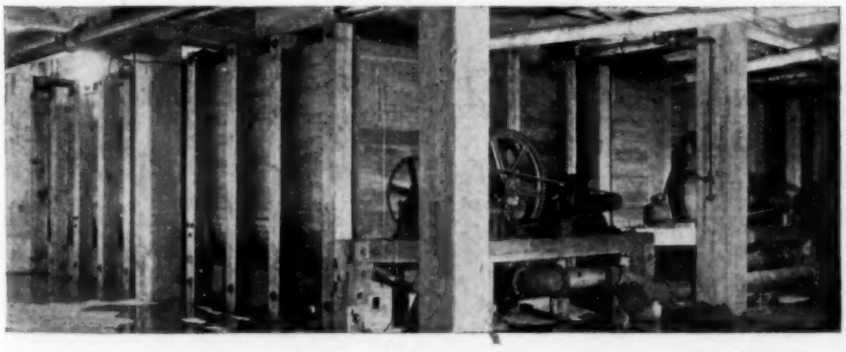
Tests were made with solutions at room temperature and at the boiling point. In the first case, samples were completely submerged for a period of 31 days. In the second, samples floated upon the surface of the solution, and were tested by boiling for one hour on each of eight days. Between boilings, fluid and test strips were at room temperature. A number of tests made upon samples coated with bituminous films were conducted for three weeks in cold solutions.

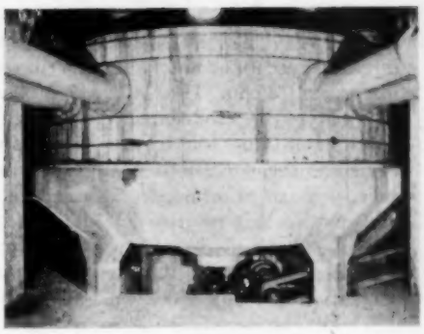


Part of a Group of Five Rubber-Lined Wood Tanks

The question of color imparted to solutions by the material of the tank is one that frequently will be of no consequence. Even in cases where color in the product would be undesirable, any coloring matter will eventually be removed provided it is not the result of charring action upon the wood. Nevertheless, since the question of coloring will sometimes need to be taken into consideration, the following summary of results is recorded.

Special Half-Round Wood Tanks With Agitators





Special Concrete-Cone-Bottom Wood-Stave Tank

In tests on hot and cold water it appeared that cypress and pine are best suited to either hot or cold water, with fir and maple standing next in order of usefulness. The question of imparted taste was also considered, with the result that cypress was found to give the best service. Fir and pine appeared to be the least desirable. Hence, comparing the water tests from the angle both of color and taste, the results may be summarized as follows:

1. Oak and redwood are objectionable from the standpoint of color.
2. Fir and pine are objectionable on account of taste.
3. Cypress is the only wood that imparts neither color nor taste after a few days. Maple is nearest to cypress in this respect.

FOLLOWING the water tests, coloring action with various hot and cold acids and alkalis was examined. Color cannot be avoided when the woods are exposed to the stronger chemicals, but it may be minimized or evaded entirely with weaker solutions by choice of the proper wood. In general, the solutions were colored in about the same order as was water with the various woods. Cypress yields the best results, with oak and redwood showing more color than the remaining woods in practically every case. It should be noted that all woods are considerably attacked by concentrated hydrochloric acid, the solution becoming opaque black. Nitric acid gains strong coloration from all woods. Fir and pine give the best results with 10 per cent NaCl. Turpentine, linseed oil and cottonseed oil fatty acids take up only slight color from any wood.

Data regarding other effects of corrosives on wood are generally more important than the foregoing. Absorption of solutions is the first of these. Weighings were made after briefly air-

Based upon a paper by S. J. Hauser and Clarence Bahlman, the Hauser-Stander Tank Company, Cincinnati, Ohio.

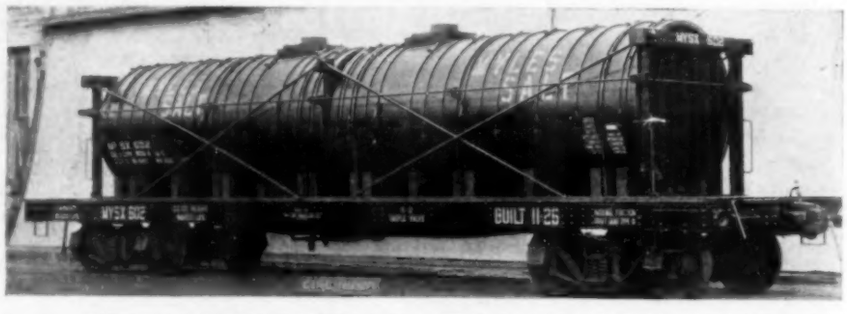
drying samples which had been submerged for one week in the case of cold liquids; and immediately upon removal in the case of hot. For any given solution of varying concentration and temperature it was found that absorption varies as the conditions change. However, this variation occurs in an irregular way, so that no general rule can be formulated. For ordinary use, the average absorption over the range of concentration for any wood and any solution will be sufficiently accurate. A table showing these absorptions is contained in the materials supplement accompanying this issue of *Chem. & Met.* (Wood Table I).

A FEW facts may be inferred from the table. Maple has the greatest absorptive capacity toward water, acids, weak alkalis and salts. Oak has the greatest absorption in strong alkalis. All woods absorb, in general, more of hot liquids than of cold, except in the case of caustic soda which is more strongly absorbed by all the woods when it is cold.

Investigation of shrinkage or expansion of wood likewise brought out irregular action on the part of solutions of varying strength. Two types of dimensional change were considered. These were called "temporary expansion" and "permanent expansion." The former represented increase in measurements of wood tested in cold liquids for one week, which were removed, wiped, and dried in air for 15 minutes; or tested in hot liquids for 8 hours and calipered immediately. After the samples had been dried at room temperature for one week, further measurement yielded "permanent expansion." In view of the erratic nature of the results on different concentrations of the same solution, the results for each solution at each temperature were averaged. A second table in the supplement (Wood Table III) gives these results in the form of temporary and permanent expansions of the different woods in hot and cold solutions.

Rubber-Lined Vat in a Paper Mill

Again generalizing, we find that all woods expand in cold aqueous solutions, but are little affected by the organic compounds tested. Upon thorough drying, not all of the expansion is lost in most cases, although certain woods will shrink below original dimensions in some few solutions. Nitric acid, caustic soda and sodium sulphide have this effect upon oak and maple. Pine and cypress alone do not shrink under the action of bleaching solution.



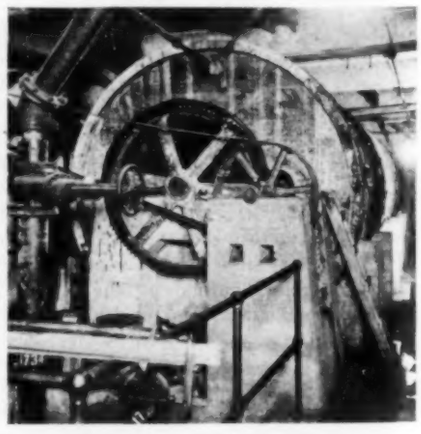
Rubber-Lined Wooden Tank Car for Transporting Hydrochloric Acid

Redwood in general has the greatest expansion in all solutions and oak the least. Hot solutions ordinarily give less expansion than cold and frequently result in shrinkage. In fact, 5 per cent NaOH solution has produced a shrinkage up to 21 per cent in the case of oak. Oak alone shows any tendency to shrink while still submerged in a hot aqueous solution. All woods shrink in the hot organic materials tested, even while the wood is still in the fluid and before there has been any drying.

The final tests were physical in nature and give perhaps the best indication of the suitability of any wood for specific purposes. Tests of appearance, hardness, warping, brittleness and so on were made on samples after one week's drying in air. Samples were subjected to cold solutions for one month and to hot solutions for eight hours. Again the supplementary section gives the results in tabular form. (Wood Table II). It is to be noted that slight softness and roughening of the grain of wood have little significance and are not indicative of unsuitability. Other characteristics which are indicated, however, lessen the adaptability of the material for the use in question.

FROM the tables it appears that HNO_3 and NaOH, of all the solutions tested, are most detrimental toward wood. Both NaOH and the stronger concentrations of HNO_3 have a tendency to cause shrinkage, especially when heated. In the case of other solutions, however, there are one or more woods that are satisfactory, at least in moderate concentrations. As an indication of the relative standing of the various woods, the number of solutions of the 38 used, which noticeably affected the test pieces, was as follows: Pine, 4; cypress, 7; fir, 8; maple, 13; oak, 15; and, finally, redwood, 22.

As a final step in the investigation, the protective action of several acid-proof paints having asphaltic and coal-tar bases was examined. Both types seemed to be equally effective in delaying action of the solutions during a 3-weeks test, although in every case, while the film was ordinarily intact and in perfect condition, the underlying wood was moist and had been slightly affected. The conclusion was reached that the protective materials, although quite resistant to the chemical action themselves, were difficultly applied in an impervious condition. Nevertheless, while no absolute protection, even from water, can be expected from these materials, their action is beneficial in that they retard deterioration of the wood. A quantitative estimate of this additional protection cannot be made, however.



Horizontal Wood Stuff Chest With Agitator

In summary, wood tanks are generally applicable for a wide range of chemicals in reasonable concentration. Cypress, pine and fir are most suitable for the common chemicals, while oak, maple and redwood are of restricted adaptability. Nitric acid and caustic soda are, among common chemicals, the most detrimental to wood and are usually best handled in other material.

PLASTICS *Play Promising Part in Equipping Modern Plant*

WERE there an ideal structural material imaginable to meet the exacting requirements of the chemical plant, this material would have to display, aside from any special requirements of hardness, elasticity or flexibility, an imperviousness to chemical and mechanical attacks from a host of common, ever-present agents—water, oil, fumes, solvents, and heat, to mention only a few. Additionally, this unknown structural cure-all would have to lend itself to accurate, rapid and economical fabrication.

Few materials approximate even such a rather modest standard of general excellence. Our strongest metal is one of the most corrodible of them: in fact, enduring service in the exposure of a plant is qualified by the chemical rather than the physical agents of destruction. If, then, electrical insulating properties be added to the gantlet of criteria, the eligible list becomes desperately impoverished. This list, indeed, will be found limited to a small group of plastic non-metals if the electrical requirements are fundamental, as the growing attention to industrial hazards, for example, is often making them.

In presenting themselves for industrial uses, the plastics can fortunately offer a number of attractive properties above and beyond the electrical; and in a proper recognition of these assets and the inevitable limitations lies their growing benefit to the chemical industry. The attempt has been made to collect from all feasible sources as many tangible, practical data on the plastics, together with the other eligible non-metallic materials, as appeared to have some bearing on the manifold problems of the plant. These data are presented for reference on the tabular supplement to the present issue of *Chem. & Met.* and, in a sense, embody in most convenient conciseness what exactly is to be gained by the chemical engineer from a full exploitation of his own creations.

Among the commercially outstanding types are to be mentioned the cellulosic derivatives, the phenolic resinous products, certain other condensation and polymerization products (such as the cumaron, urea-formaldehyde, and vinyl compounds), the casein plastics, the cold-molded plastics, and the rubber products, the latter of which are treated elsewhere in this issue. Particularly helpful in preparing this discussion of plastics have been the co-operation of Carleton Ellis, Montclair, N. J.; A. V. H. Mory, of the Bakelite Corporation; A. F. Randolph, of the du Pont Viscoloid Company; and James F. Walsh, of the Celluloid Corporation, who in such large measure shares credit for the compilations on the supplement.

Cellulose Nitrate and Acetate

ALTHOUGH of a venerable familiarity to the public through their use in novelities, toilet ware, pen barrels, and even combustible collars, the pyroxylin plastics received their industrial initiation appropriately within the nitrating plants in which they were made. Here, in connection with the storage of pyroxylin, they were successfully applied to both the circulating piping and the tanks themselves. Other processes have meanwhile lent themselves to similar applications of pyroxylin plastics, which have offered the advantages of specific chemical inertness with attractive surface qualities, so that linings made from them offer a smooth exterior free from metallic or wooden contamination.

It is because of their conspicuous shortcoming, flammability, that plastics from nitrated cellulose are now being supplemented by those from the acetate. While neither is qualified for high-temperature work above about 60 deg. C., the latter is inert to the extent of wood at least, and is hence invading and expanding the field of application of the cellulose group.

In the matter of linings of all sorts, for example, both compounds are now being utilized in the convenient form of veneers. In paper making, the acetate is used on the drying rolls and other parts where weak (but not organic) acids may be present. Further, it lends itself to gears, and to surfaces in the plant that need a durable coating. The case of asbestos board carrying an acetate veneer had the obvious advantage of inertness to fumes and fire, in addition to a convenience of cleaning beyond ordinary finishes. Numerous incidental uses of this nature have proved attractive for both compounds: smooth, washable working surfaces, chart and record coverings, coatings on paddles, dipping baskets and the like.

What has been one of the major attractions of the simple compounds is their transparency, a quality which, combined with their mechanical flexibility, is responsible for their use in films and transparent coatings of all sorts. Shatterproof glass, a "sandwich" with either of the plastics as its interleaved morsel, owes its superlative features to both its glassy rigidity and surface hardness and its absolute cohesion under the strongest impacts. Although fortunately unlike automobile driving in its fondness for sudden impact, the chemical plant undoubtedly has uses for "safety" glass wherever transparent shields, masks, and guards are advisable. With their transparency the cellulose plastics offer the further possibility of unlimited integral coloration, which, where applicable, cannot be removed by mechanical abrasion.

Both cellulose plastics are now obtainable as molding powders as well as in the form of sheets, tubes, rods, and films, indicated above. Thus far the use of the powder (more lately in the case of acetate) has extended to the various every-day articles of commerce, in which chemical engineers may be interested in only a non-professional way; however, as the properties become known, the possibilities of the pressed-powder aggregate will soon give it access to the industrial plant.

AT THIS point, too, the important group of cellulose ester coating solutions deserves mention. Both the nitrate and acetate are employed as the "dope" for aircraft surfaces, with the acetate now gaining headway because of its non-flammability; the protection offered concerns principally water, oil, gasoline, sunlight and atmosphere (destructive to fabric), and impermeability to gases. The brittleness of acetate films is counteracted by softening agents in the solution. Metal parts of all sorts are likewise coated with pyroxylin or acetate lacquers, applied by brushing, dipping, and spraying. Since the primary purpose is always protection,

adhesion to the metal must be effected by other constituents and priming coats. The materials incorporated to gain adhesion, gloss, and durability now include a number of synthetic resinous materials.

The cellulose plastics, then, offer a very favorable combination of properties so long as temperature requirements remain moderate: while both are, strictly speaking, flammable, the fire hazard is altogether negligible in the case of the acetate. Lighter in weight than the metals and glass, they absorb shock without fracture, and are resistant to most chemical influences such as moisture, many organic chemicals, and weak acids. Exceptions to this are steam, strong acids, alkalis, formic and acetic acids, and some of the organic solvents. It is of further interest to realize that, despite their comparatively long-lived commercial success, the cellulose derivates remain the object of intensive technical study and development.

Phenol Formaldehyde Resinoids

AS MOST PROMINENT representatives of the new diverse class of synthetic condensation products, the phenolic resins display some especially interesting propertes: their excellent electrical behavior, their precise workability, and their obdurate resistance to change. Consultation of the tabular supplement will further impress these characteristics, especially where chemical and mechanical attack are concerned. It may be said that this group shines, not because of some single surpassing property, but because of a sufficient merit in a large number of properties.

These advantages are gained not only by the passivity of the pure resin but additionally by the incorporated fillers that are appearing increasingly in commercial products. These constituents consist usually of wood flour, cloth, paper, mica or asbestos—in fact it is a compounded asbestos resinoid that is now finding reception in Europe in the form of really sizable acid tanks. Additionally these compounds are accessible in solutions for the coating of equipment made of other materials.

The limitations of these resins are an inherent amber coloration and, like all other plastics, susceptibility to strong acids and alkalis. With their advantage of precise and permanent molding is combined a necessarily specialized molding technique, involving expensive dies and hydraulic equipment, which has hitherto limited the size of products. It is hoped, however—and the European development mentioned above lends strength to the hope—that technology will eventually remove this obstacle. For many practical purposes the varnishes are meanwhile sufficient protection on large areas.

In view of the conceded mechanical, chemical and electrical excellence of the phenolic resins, the number of industrial applications is already considerable. Perhaps no better illustration of their possibilities can be offered than the subjoined selection of cases from practice.

Plating barrels of phenol resinoid are being used in deposition of copper and nickel. They wear longer than the wooden barrels previously employed and, being much less absorbent, afford better electrical insulation with lower current loss from

Phenol Resinoid Plating Barrel

leakage. The plating speed has been considerably increased and the barrels last much longer than when made of wood. Molded phenol resinoid agitator paddles are being successfully used in the same plating baths.

A felt sizing machine employing weak nitric acid is making use of a number of phenol resinoid gears in a train of steel gears, thereby not only reducing the noise of operation but protecting the steel gears against corrosion by electrolysis.

A water ozonizer has moving parts and valves of molded phenol resinoid which, unlike the metal parts previously employed, are not corroded by the ozone to which they are exposed. In this same apparatus laminated phenol resinoid tubing is employed for the smaller pipe lines.

Pump vanes made of phenol resinoid are effectively applied to the handling of corrosive mine water and stand up well under the abrasive action of the accompanying grit.

Phenol resinoid meter disks are sometimes being used to replace hard rubber, which, though highly impervious to water, softens if hot water gets into the meter.

Molded phenol resinoid containing asbestos filler is being successfully used for valve disks to hold high-pressure steam. A similar material is employed for electric heater connectors.

Phenol-resinoid impregnated fibrous products are filling a definite need as guides and core tubes in the textile industry. Here the need is for resistance to steam and to dye solutions.

The usual rigidity of hardened phenol resinoid has been modified with the production of forms that are tough and flexible. These are suitable as protective coatings for kettles and other chemical equipment subjected to large fluctuation in temperature. The necessity of baking to develop the virtues of these coatings is the limiting factor, but they are finding increasing use as protective coatings for corrodible metals and other less resistant materials, where size militates against the application of complete resinous construction.

Thus an impeller made of a supposedly acid-resisting alloy produced metallic contamination in a toothpaste containing small amounts of hydrochloric and tartaric acids. A coating of phenol resinoid varnish prevented contamination.—Filter plates coated with phenol resinoid varnish are being successfully used in contact with a solution of oxalic acid.—Aluminum spools employed in the rayon industry are similarly protected, while another industry employs resinoid-coated aluminum trays in the presence of fumes of sulphuric and hydrochloric acids.—Also wooden fume stacks are thus protected against sulphuric and acetic acid fumes.—A steel centrifugal basket coated with phenol resinoid varnish has stood up for years in the handling of liquids containing dilute phosphoric acid.

Other illustrations might be given, but something of the possibilities will again be suggested by an examination of the supplement to the present issue. There are many varieties of these products, developed to meet special needs. If some phenol resinoid product looks promising for the use intended, the problem becomes that of choosing the variety which seems likely to be best suited. This is the work of one thoroughly acquainted with the characteristics of these products, and also with their possibilities, if the development of a new variety appears to be called for.

Other Plastics of Commerce

FURFURAL RESINS—Because of their origin in agricultural wastes, such as oat hulls and corn cobs, these products were once embarrassed by some measure of popular attention. In general their properties have invited comparison with hard rubber rather than with the resins, which they resemble chemically as derivatives of phenol and furfural. But of late their commercial development has become extensive enough to insure them of a rôle in the field of plastics generally.

Phenol-furfural condensation products were primarily intended for the reproduction of quality printing halftones, a purpose that gives some idea of the precision and gloss obtained in molding them. They occur in two classes: a black acid-reaction product, and a brown basic-reaction condensate. These types have meanwhile been developed for other industrial purposes, so that they now appear in a large variety of colors, and in combination

Rayon Spinning Bucket of Phenol Resinoid

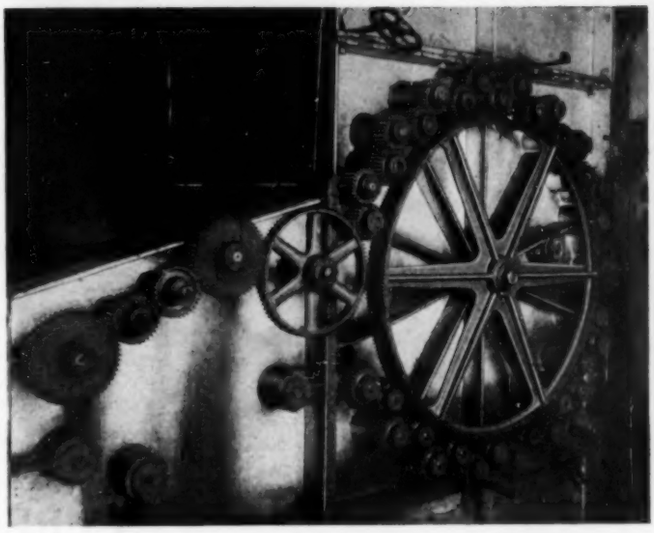
with the several kinds of filler, e.g., wood flour, asbestos, mica, and so on. As a varnish the resin occurs dissolved in an alcohol solution; the molded resin, however, is a hard, infusible and resistant product.

Urea-Formaldehyde Resins—Condensation and polymerization products from formaldehyde and urea or thiourea are a class of plastics whose commercial availability dates only to recent years, although several brands are known in Europe and America now. Some of their pertinent properties are listed on the supplement accompanying this issue, but it is of further interest to note that an initial condensation product is soluble in water and has been recommended as an adhesive; further treatment produces the clear resin, insoluble in water, alcohol, oil, organic solvents, and weak acids and alkalis. Especially attractive properties of the class are its stability to mild heat (up to 140 deg. C.), its non-flammability, and the absolute clarity of the pure product, which consequently has an unlimited color range and any degree of transparency. This resin can be applied in thin sheets to metal, and metallic parts can be incorporated in it. A difficulty in the past has been its tendency to craze (develop cracks); apparently, however, corrective methods have been applied since then.

One of its first commercial applications, although altogether of a non-industrial nature, has been directly concerned with chemical corrosion. A large British steamship line plying to the tropics decided to end its perennial problem of polishing metallic maritime fittings by substituting this type of resin. After two years this decision has apparently proved so beneficial that passenger liners constructed in that country have consistently adopted the new practice in combating corrosive atmospheres.

Apart from their resistant properties, their optical and physical characteristics also determine the uses of urea-formaldehyde plastics. Where abrasive action is unlikely, their permeability to ultra-violet rays stands to advantage, while their clear transparency suggests their use as containers for the numerous liquids which they resist; in chemical-optical reactions their application hence lies directly at hand.

Glycerol-Phthalic Anhydride Resins—Although now available in solid, machined form, the members of this group had their introduction commercially a relatively short time ago as protective and insulating lacquers and lacquer constituents, either as the simple compound or as a chemically modified product. Their industrial value, in addition to resistance to oil and many common corroding agents, is due in both cases to their adhesive and film-building qualities. Thus the lacquers themselves, while not quite so hard as the customary types, adhere very well to metal, wood, and cloth. And an aluminum lacquer of this group, especially suited for coating metals, is said to withstand up to 600 deg. F. As lacquer constituents and balsams, members of this group are used generally in about three parts to one of nitrocellulose, although the purpose proscribes the exact ratio. It is their outstanding property to impart gloss, flexibility and durability to the pyroxylin—in fact, the latter improvement depends directly on the amount of incorporated resin, which can be blended in any proportion. The balsams function primarily as plasticizers. Its weather-proofing and protective qualities, as well as its clearness, make this group additionally attractive as modifying agent in nitrocellulose coatings.



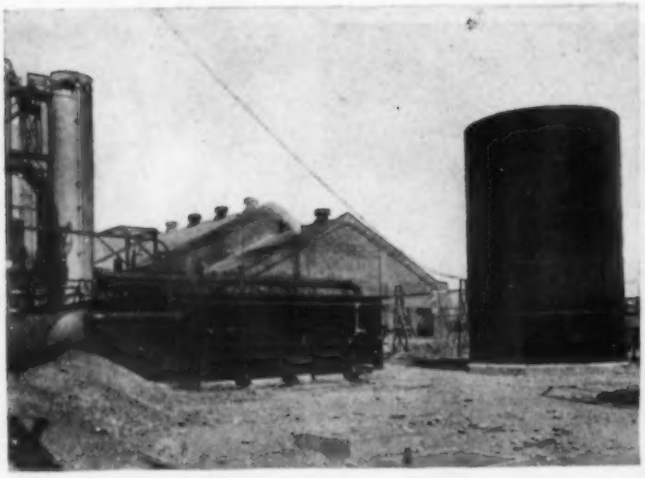
In Felt Sizing Machines Phenol Resinoid Gears Withstand Fume and Splash From Weak Solution of Nitric Acid and Mercury

Cumaron Resins—The cumaron resins of commerce in recent years have become, unlike their forerunners, clean, inoffensive condensation products. The five or six recognized grades vary in melting point from 50 to 150 deg. C. and in color from black to a pale rosin yellow. Because of their solubility and miscibility in a great number of common organic liquids and fats, cumaron resins have found their widest application in the paint and varnish industry, which has developed them further as waterproof coatings for cement, asbestos, and molded articles. Apart from their further use as a component of vulcanized rubber these resins have lent themselves as constituents of cold-molded and hot-molded plastics, in which case their high dielectric constant and water-proofing qualities appear to advantage. In a pure form they are handicapped by brittleness and low tensile strength.

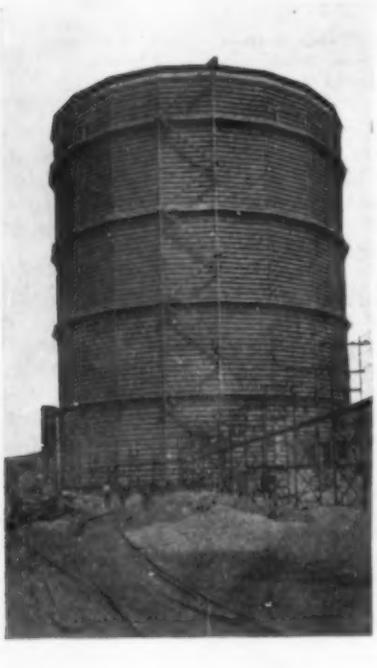
Vinyl and Styrol Resins—This type of compound is another new arrival in the commercial field, but its possibilities are being developed both here and in Europe. The vinyl resins are odorless and colorless, stable to heat up to about 125 deg. C., and indifferent to most organic solvents except certain ketones, aldehydes, and mixtures; they are insoluble in water and alcohol. Their determined applications thus far cover the usual domestic nick-nacks in addition to solutions as varnishes and dipping lacquers.—Cost of manufacture has hitherto retarded the employment of styrol plastics, since their resistance to a large number of chemical agents, including water and alcohol, and their vitreous transparency make them eminently eligible for everyday and industrial purposes. They are now available, however, as molding powders and yield, with suitable pigments, all degrees of transparency.

Casein Plastics — Wherever their most conspicuous handicap—lack of precision in the presence of moisture—is of little importance, the relative cheapness of casein plastics recommends them for numerous incidental purposes within the plant, since they offer resiliency, insulation to heat and electricity, and low flammability. Their possibilities and limitations are readily evident from a consultation of the data chart inclosed in this issue. In general their very widespread use has been principally confined to non-industrial articles of commerce, where their function is partly decorative and partly utilitarian, as in the case of handles, grips, casings, fixtures, and the like. In these cases their workability and coloration have been guiding factors.

Cold-Molded Plastics—This group differs from the hot-molded type in that it is plastic at ordinary temperatures, at which the shaping can take place (hence cold-*molding*). Hardening then results from the controlled application of heat, which "sets" the binder. Binders generally consist of pitch, asphalt or, more latterly, synthetic resinous products; the fillers vary from asbestos and other fibers to mineral materials such as clays and mica. Outstanding features of the group are great cheapness and good electrical and heat resistance, so that they have found very widespread employment wherever appearance is not a consideration and where mechanical impact is not likely. At present, hot-molded products of similar composition are tending to invade their place in commerce, especially because of their greater resistance to impact.

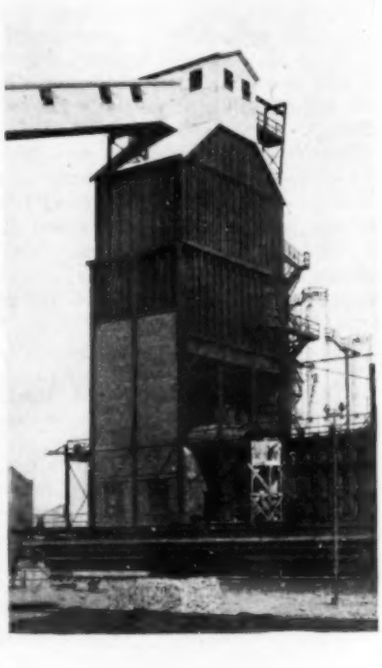


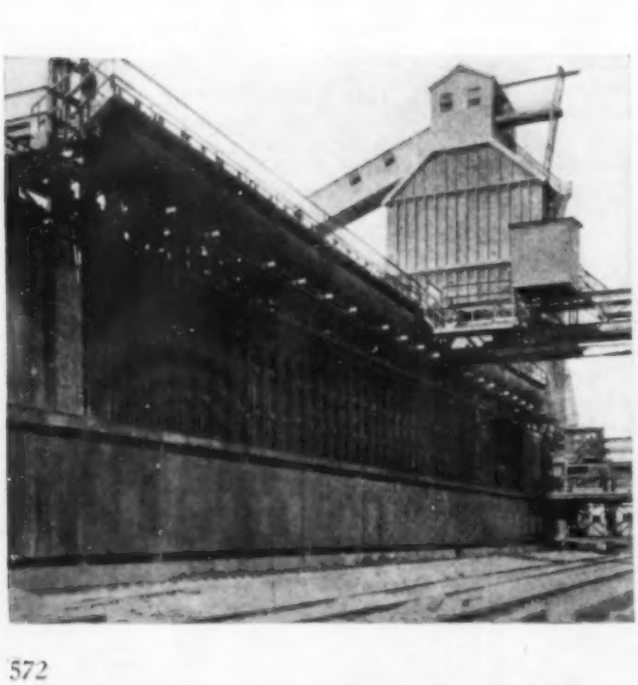
PURE IRON
in a Coke Plant



IN BUILDING the new Koppers byproduct coke plant of the Hamilton Coke & Iron Company at Hamilton, Ohio, ingot iron was largely used in an effort to reduce corrosion. While the investment in pure iron was naturally a little greater than would have been required if steel had been used, the increase was nevertheless incurred in the belief that equipment life could thus be increased and made more nearly predictable.

WHEREVER sheets or plate were involved, ingot iron was used. The surrounding views show some of the more important pieces of equipment. At the left are the primary coolers, hot drain tank, flushing tank and ammonia liquor storage above; the 5,000,000 cubic-foot waterless gas holder directly below; and the collecting main and other ingot iron parts at the bottom. The upper right shows storage tanks and, below, a bin with pure iron bin plates and galvanized ingot iron sheeting. At the lower right are acid tanks, saturators, tar extractors and reheaters.





WHAT CAN *We* USE?

Wherein the crystallized experience of modern industrial practice in regard to many corrosion problems is briefly presented

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DETAILED discussion of the large number of processes that comprise the industries using corrosion-resistant materials would be almost encyclopedic in character. It would encompass heavy chemical manufacture, dyestuffs synthesis, oil production, rayon spinning, paper making and many other human and industrial activities. It is possible, however, by discussing the method of handling a few raw materials essential to many industries, to strike a note of interest common to the users of construction materials in seemingly diverse industrial activities. For instance, sulphuric acid and nitric acid are almost universally used or have to be handled in producing steel, oil, explosives, rayon, paints, lacquer, fertilizers, paper, motion-picture film, and plastics. Therefore, the method of handling these two acids should claim first place in any discussion.

Sulphuric Acid—Aside from the large tonnage of production of sulphuric acid and the problem of designing plant equipment used for this production, the acid is generally a factor in considering plant equipment for many other processes. Since in general the same principles that govern the selection of material for handling sulphuric acid in process of manufacture may be applied in designing equipment for processes in which this acid is an essential raw material, a discussion of sulphuric-acid manufacturing equipment will serve as a manual for other process plants.

This important acid flows into the chemical industry from several sources, including contact catalysis and lead-chamber manufacture, recovery of spent mixed acids and waste materials, or concentration of weak solutions to more usable strength. In the contact plant a generally higher concentration range has to be handled and the problem of selecting material for the higher-concentration range is relatively simple. The range of concentration is from about 90 per cent to 109 per cent (dissolved SO_3) and the temperature may reach as high as 250 deg. F.

Usually in contact manufacture the raw materials are sulphur and air. The intermediate ingredients that have to be handled at certain stages of the process are SO_2 and SO_3, both wet and dry. These two gases are present under temperatures as high as 800 deg. F. Probably the most difficult problem lies in the handling of these two materials, but the corrosion may be controlled largely by regulation of the moisture content. Assuming proper control, the materials used may be iron and steel, as is most of the equipment in the contact plant.

In the lead-chamber plant the concentration of H_2SO_4 seldom exceeds 60 deg. Bé. Aside from the corrosive nature of the low-strength sulphuric acid, the problem of selecting materials is further complicated by the presence of oxides of nitrogen at certain stages in the process. Chemical lead and acid-proof stoneware are the materials that are most satisfactorily used in this case.

Probably the greatest corrosion by sulphuric acid is encountered in the recovery and concentration plants. Sulphuric acid is peculiar in that the greatest corrosion of material occurs in the lower and upper ranges of concentration; and the most severe range is between 75 and 85 per cent H_2SO_4. The recovery and concentration of the acid involves the handling of concentrations from 50 to 93 per cent. Lead may be used in the range from 50 to 85 per cent H_2SO_4 at temperatures as high as 250 deg. F. Between 85 and 100 per cent, steel and cast iron must be used, particularly at the higher temperatures. High-silicon iron, of course, is universally resistant to all strengths of this acid at all temperatures, and is satisfactory provided the temperature changes are not severe.

In general, the various methods which introduce sulphuric acid into the chemical industries utilize fairly simple reaction vessels, storage tanks, pipe lines, pumps and pipe-line fittings. For reaction vessels, tanks and pipe lines, lead may be used in the weaker range at temperatures not in excess of 250 deg. F. Above this, steel and cast iron are the most practical materials. For pumps and pipe-line fittings hard lead and cast iron are generally used, depending upon the concentration and temperature conditions. There has been considerable success with the use of Duriron for pumps moving the acid about the plant. It has been found that steel and cast-iron pumps cause a rather excessive maintenance.

Sulphur Oxides—While SO_2 and SO_3 do not cause a great deal of handling difficulty in sulphuric-acid manufacture, there are chemical processes in which these two gases are used as ingredients or are formed as decomposition products. As long as the moisture content is relatively low, they may be handled in steel and cast iron. In the presence of moisture, however, the exceedingly corrosive sulphurous acid is formed and the difficulty in handling is increased considerably, depending upon individual process conditions. Wood, stoneware, Duriron, and glass may be used with some degree of satisfaction. Wood is frequently used for exhaust stacks.

Nitric Acid—Nitric acid is almost equally as important as sulphuric acid in the chemical industries. If there are practically no impurities, this acid may be handled under all conditions of temperature and concentration by using high-chromium alloys. Previous to the development of these very useful alloys, the handling of nitric acid constituted a very difficult corrosion problem and dubious satisfaction had to be

derived from the use of such materials as high-silicon iron, glassware and stoneware in equipment that was quite crude and inefficient. All types of equipment can now be obtained in the stainless alloys. Quite contrary to the usual rule, the mechanical properties as well as corrosion resistance of these alloys are exceptionally good.

Alloys containing as low as 14 per cent of chromium may be used satis-

factorily providing the carbon content is less than 0.10 per cent. However, the mechanical properties of alloys of the lower chromium content are not particularly attractive. By increasing the chromium to 15 or 16 per cent and maintaining the same low carbon, an improvement in physical properties and corrosion resistance is obtained. Further increase of chromium content somewhat enhances the corrosion resistance to nitric acid. The addition of about 8 per cent nickel to 18 per cent chromium in iron results in slight increase in corrosion resistance over that of the chromium alloys without nickel. It is to be doubted that the higher cost of increased chromium and added nickel is justified by the increase in life of equipment as far as nitric acid is concerned.

The presence in nitric acid of small amounts of hydrochloric acid, chlorine and hydrofluoric acid causes quite rapid corrosion of the high-chromium irons and chromium-nickel-iron alloys. They cannot, therefore, be used in certain nitric-acid recovery processes in which these impurities appear.

Mixed Acids—Sulphuric and nitric acid mixtures may be handled in iron, lead or stainless alloys, depending upon the ratio of sulphuric to nitric acid, and the water content. For most nitrating acids steel and cast iron are satisfactory, since the concentration range for these acids is approximately from 20 HNO_3 — 60 H_2SO_4 to 50 HNO_3 — 50 H_2SO_4. It is necessary to use lead when the nitric content falls below 20 per cent or if the water content exceeds 30 per cent. The stainless alloys may be used with reasonable success to handle mixed acid containing as low as 10 per cent HNO_3 with the sulphuric-acid content as high as 70 per cent. Sulphuric acid alone attacks stainless alloys; but if sufficient nitric is present to produce a passive surface, the action of sulphuric acid is retarded. The most widely used mixed acids are sufficiently high in sulphuric to show a remarkable avidity for water. This property is responsible for rapid attack of steel tanks and pipe lines, due to induced dilution.

Ammonium Nitrate—The manufacture of ammonium nitrate from nitric acid and ammonium hydroxide may involve considerable handling difficulty at certain stages of the process. The greatest corrosion of materials is probably in the concentration and crystallization of the ammonium nitrate solution which contains about 50 per cent NH_4NO_3. This step in the process may be carried out in large shallow pans containing agitating arms and steam coils. These pans may be made of cast iron and may last for several years. The coils, however, which may be either steel or cast iron, may fail in a few days. This rapid failure is caused by the presence of impurities such as ammonium chloride and slight amounts of acid or by galvanic influences. A great deal of corrosion takes place on steel work and pipe lines exposed to vapors arising from the evaporating process, but such rapid failure as that of the coils does not occur. The stainless alloys may be used for the coils and for structural members subjected to the vapors in the crystallizing room. As in the case of nitric acid, the presence of chlorides in any appreciable amount will seriously corrode stainless alloys in this service.

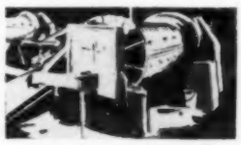
Ammonium Hyroxide—This compound may be handled in cast iron and steel, but the reaction vessel in which mixture with the nitric acid occurs to form ammonium nitrate, must be lined with brick or tile. Stainless iron may be used to replace the lined steel reaction vessel, providing of course the nitric acid used is free of the objectionable impurities. Copper and copper alloys should never be used for handling any ammonia compounds.

Anhydrous Ammonia—Aqua ammonia, formerly used as the source of NH_3, has in the past few years been largely replaced by anhydrous ammonia, containing 99 + per cent NH_3. Handling this liquid does not involve any corrosive difficulties, but due to the necessity of storing and transporting under pressure, relatively high strength vessels must be used. Carbon steel is entirely satisfactory for this purpose.

Hydrochloric Acid — Hydrochloric acid is the most difficult of the commercial inorganic acids to handle. While several materials of construction have been used for equipment, probably the most satisfactory is rubber, which is applicable at temperatures not exceeding 150 deg. F. Rubber-lined wood storage tanks, rubber-lined steel reaction vessels and pipe lines, hard-rubber valves and fittings are available for this purpose. Where the temperature exceeds 150 deg. F., as in condensers, fused silica, glass or stoneware may be used. The commercial concentration range of hydrochloric acid is about 0 to 30 per cent HCl. Under certain conditions of temperature and concentration, Duriron may be used, but standardization on soft and hard rubber and fused silica presents the most satisfactory arrangement at present. Chlorine may be handled satisfactorily in steel and cast iron if dry, but if moisture is present stoneware and glass must be used.

Acetic Acid—A rather troublesome member of the organic acids, and one of the most important, is acetic acid. It exhibits somewhat the same characteristics as sulphuric acid in that the most severe corrosion is caused by two or three concentration zones within the over-all range. For instance, between 99 and 100 per cent, a fraction of a per cent may cause an increase of corrosion rate that is many times that in acid of less than 99 per cent.

Several materials are available for handling this acid, but in the manufacturing process using calcium acetate and sulphuric acid, copper is used quite extensively for certain stages of the process and brick-lined wood tanks for other stages. The entire range from 0 to 100 per cent at the process temperatures may be handled with these materials. Copper has been found to be somewhat more reliable than aluminum although the latter is often used in handling acetic acid of high purity. Copper is objectionable in that corrosion takes place rather rapidly in the presence of air at



elevated temperatures. By taking such precautions as proper venting arrangements, this difficulty may be largely controlled.

The stainless alloys are being introduced as materials for handling certain concentrations of acetic acid, but there has not been sufficient time to prove their reliability.

Sodium Hydroxide — Caustic soda may be handled almost exclusively in cast iron and steel. The greatest corrosion difficulty is in the concentration of this alkali from 30 per cent to 100 per cent NaOH. By introduction of small amounts of nickel and by reduction of the normal amount of sili-

con in cast iron, reasonably satisfactory equipment for this service can be obtained. Steel can be satisfactorily used for 80 per cent NaOH and a mixture of 30 per cent potassium hydroxide and 70 per cent sodium hydroxide. At elevated temperature, caustic embrittlement of steel and cast iron may cause untimely failure of equipment, particularly if the metal is under strain. Where this condition is to be coped with, it may be found advantageous to use either the stainless alloys, in which case the 18 to 20 per cent chromium type is most practical, or nickel. A caustic evaporator in which the liquor comes in contact with nothing but nickel or cast iron is now widely used in the alkali industry.

Alum—The corrosion difficulties met in the manufacture of alum are largely those that are involved in handling sulphuric acid. It is generally made from bauxite and sulphuric acid of 93 per cent and 80 per cent H_2SO_4 strength. The equipment used consists of settling tanks, thickening equipment and digesters. The tanks are lead- and brick-lined wood. The piping is lead. Some of the pumps are Duriron, others lead. At certain stages in the crystallizing operation, copper has been used to advantage.

The most troublesome part of the equipment is that subjected to wet SO_2 and SO_3. Fortunately, this is a relatively small part of the total equipment and is readily replaceable. The most satisfactory material for exhaust stacks on digesters where the mixture of bauxite and sulphuric acid takes place is wood impregnated with asphalt or tar. The only difficulty with the thickening equipment is with erosion of the lead agitating members. This is usually caused by misalignment and is really not a normal operating condition.

Dyestuffs—The plant manufacturing dyestuffs is a veritable proving ground for corrosion-resisting materials of construction. In addition to a wide range of severe-service conditions, the problem of contamination prevention assumes almost paramount importance. A dyestuffs plant consists of many small-batch operations and a great number of different products are made. A large proportion of the total maintenance cost may be attributed to corrosion.

In spite of the great variety of products and ingredients, a survey of all the operations will show that a large part of the maintenance caused by corrosion is due to a relatively few acids and chemical compounds. Acetic, hydrochloric, nitric and sulphuric acids and strong alkalis are the chief offenders. Dyes and dye intermediates cause some trouble, but it is principally of the contamination type.

The same materials and rules of selection as described in foregoing paragraphs may be used to reduce the cost of maintenance caused by the more common acids and alkalis. A listing of materials used most satisfactorily for dyes and intermediates would be extensive; but, in general, the metals and alloys of nickel, tin, zinc, copper and silver assume greatest importance for this purpose. Contamination problems are generally solved by using enamel, glass, silica and other non-metallic materials of construction. Most of the cases of corrosion and contamination by dyes and intermediates have to be dealt with on their individual merits.

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METALS AND ALLOYS

With Resistance to Sulphates And Sulphuric Acid

By Peirce D. Schenck
President, The Duriron Company, Dayton, Ohio

MATERIALS RESISTANT to the corrosive effects of various strengths of sulphuric acid and the sulphates cover a wide range, from lead through various ferrous and non-ferrous alloys to gold and platinum. The characteristics of the metals are well understood, but the varied, and in some cases totally unexpected, effect of various strengths of sulphuric acid and different sulphates on alloys has been only studied in a few specific instances and the information available is rather limited.

Few, if any, commercially available metals or alloys are satisfactorily resistant to sulphuric acid of all concentrations and to all sulphates. Each alloy has certain advantages or disadvantages in regard to forming, machining, welding, casting and cost.

In discussing the effect of various solutions on the alloys, unless otherwise specified all references are made to solutions at temperatures in the neighborhood of 80 deg. C.

MUCH lead is used in the form of sheet and pipe for containing and conveying sulphuric acid and sulphate solutions. The ease with which sheet and pipe can be bent and autogenously welded (lead burning) adds greatly to the usefulness of this material. It resists satisfactorily cold sulphuric acid of all strengths up to 95 per cent and hot sulphuric acid of all strengths up to 80 per cent with temperatures up to 205 deg. C. For some purposes antimonial lead is used in preference to chemical lead on account of its greater strength. Considerable progress has been made in the manufacture and use of lead reinforced with a stronger metal such as steel. The low cost of the lead and the relatively high salvage value are important considerations.

ALUMINUM bronzes containing from 7 per cent to 11 per cent Al and from 1 to 3 per cent iron, can be used to advantage in hot, weak sulphuric acid solutions. At about 40 per cent concentration their solubility increases rapidly and their value as an acid-resistant material ceases abruptly at about 50 per cent concentration. These bronzes can be used to advantage with the sulphates of aluminum, ammonium and nickel. They have not proved entirely satisfactory with sulphates of barium, magnesium, nicotine or zinc, and are unsuitable for use with copper, ferric, and mercurous sulphates.

In some processes the presence of copper salts in solution is a distinct disadvantage, and as there will always be a small but constant addition of copper salts to the solution, in such processes aluminum bronze should be avoided.

A considerable variation of opinion exists as to the actual value of the aluminum bronzes, due probably to the fact that sound, homogeneous aluminum bronze castings are difficult to produce and unfavorable opinions as to the material have been based in many cases on castings furnished by manufacturers who have not appreciated the exacting requirements of the chemical industry.

The copper-silicon-manganese alloys have much the same characteristics in resistance to corrosion by sulphuric acid and the sulphates as have the

aluminum bronzes, and, of course, have the same objections as to the addition of copper salts to solution. The corrosion characteristics do not necessarily parallel the aluminum bronzes in all solutions but in the type under discussion they may be considered similar to them.

High-nickel copper alloys show a resistance to hot, weak solutions of sulphuric acid of about the same degree as the aluminum bronzes. Under conditions where considerable aeration is present, the nickel-copper alloys show up better than the aluminum bronzes; while in the absence of aeration, laboratory tests at least indicate that the aluminum bronzes are slightly more resistant. The nickel-copper alloys will successfully withstand slightly higher concentrations than the bronzes.

THESE alloys are excellent for use with nickel, zinc, barium and aluminum sulphates provided the solutions carry no ferric iron. As with other alloys containing large percentages of copper, a high ferric iron content is detrimental to their successful use.

These alloys are valuable and are frequently used for handling copper sulphate containing free sulphuric acid, but where the copper content of the acid is high, there is a tendency for the copper to plate out on the alloy. They are not recommended and should not be considered for use with ferric sulphate.

These alloys are available in a wide variety of rolled stock, are readily fabricated and have excellent physical properties.

Chromium-nickel steels of the 18-8 type are not recommended for use with sulphuric acid at any strength or temperature. While they show in some cases fair resistance to cold solutions, there are many other more suitable materials. The chrome-nickel steels, however, show excellent resistance to copper-sulphate solutions and, as a matter of fact, the straight chrome steels over 18 per cent seem to be at least as resistant as the chromium-nickel steels. Apparently any chrome or chrome-nickel steel with over 18 per cent chromium content will exhibit excellent resistance to copper sulphate with a smaller percentage of free sulphuric acid. The copper salt in this case apparently acts as an inhibitor.

STEELS of this type have also been recommended as being unaffected by aluminum, ammonium, and magnesium sulphates.

Recent tests with hot mercurous sulphate indicate that the 18-8 type of steel is practically unaffected.

These steels can be obtained in either rolled or cast form and are comparatively easy of fabrication. While they are limited in their application in this particular corrosive field they should be seriously regarded as available materials of construction.

Nickel-silicon steels are a new type, ranging from 15 to 35 per cent nickel and containing approximately 5 per cent silicon. They have about the same range of resistance to sulphuric acid as the aluminum bronzes and consequently should not be considered where the concentration is over 40 per cent. In fact, their resistance diminishes rather rapidly above 35 per cent H_2SO_4. Within this range, however, they are extremely resistant.

They are also recommended for use with aluminum, ammonium, magnesium, nickel, nicotine and zinc sulphates. The steels of the lower nickel content are not recommended for ferric or mercurous sulphate but the grade containing 35 per cent nickel is extremely resistant to both of these solutions.

These steels are austenitic and ductile, and are distinguished by their ease of welding and fabrication.

As far as resistance to corrosion is concerned, the high-silicon irons have an enviable position as they are extremely resistant to all strengths and temperatures of sulphuric acid and have been successfully used for years with all of the sulphates. Their limitations, however, in regard to fabrication and physical characteristics make these particular alloys unavailable for many applications.

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SLUSHING OILS

For Corrosion Resistance

RECENTLY the Bureau of Standards has had numerous inquiries regarding information as to methods of protecting from corrosion metal in storage for rather long periods. These requests generally refer to the protection of metal articles which are of such a nature as not to allow the application of metallic coatings, such as galvanizing, or of vitreous enamels, paints, or varnishes. It is obvious that with bearing parts of machinery, coatings such as the above, which form dry and hard films and cannot be easily removed, are not suitable. Our attention is therefore confined to a consideration of protective coatings which remain in a soft condition so that they can be easily removed at any time.

Regarding the length of time these coatings will afford adequate protection, there is little information available. It is well known that good oil paint will protect steel for several years when exposed to the weather, and that a good varnish will protect steel for several months. The protection afforded by paint and varnish to articles when kept indoors is very much greater than when exposed to the rays of the sun. While no data based on experiments are available, it is safe to assume that coating with a good grade of varnish and storing protected from the weather may be expected to preserve metal for several years. Paint under similar conditions may be expected to preserve metal for a considerable number of years. As mentioned above, however, these two types of materials are not applicable for use on the bearing parts of machinery, or on many metallic articles which must be protected from corrosion. Such bright metal is protected by coating it with a layer of non-drying grease, usually known as slushing oil or slushing compound.

Slushing oils or slushing compounds are of a varied nature, sometimes being straight mineral greases (petroleum residuum, such as petrolatum), sometimes mixtures of mineral and animal greases with or without the addition of soap (such as lime rosin or lime fatty acid soaps), finely divided mineral matter, and volatile solvents. Sometimes the petroleum base is mixed with rosin or rosin oils. Mineral oils as fluid as light spindle oils have been used for this purpose, but from the discussion which will follow it will be seen that such thin products are of very doubtful value except for very limited and particular purposes.

An ideal slushing compound is one which can be easily applied to all kinds of metal surfaces by a variety of methods. It should coat the surface with a sufficiently thick and impervious film to exclude moisture and air (to prevent rusting), should remain in position for an indefinite length of time and yet be completely removable from the surface without undue labor. The material should itself have no corrosive action on any kind of metal. It is believed that the above statements give the essential requirements of a slushing compound.

Extracts from "Slushing Oils," by P. H. Walker and L. L. Steele, technologic paper No. 176 of the U. S. Bureau of Standards.

PATENTS ISSUED
Aug. 6 to Aug. 27, 1929

Pulp, Fiber, Glass and Sugar

Method of Making Fiber Board. Otto Mantius, New York, N. Y.—1,723,051.

Process of Making Waterproof Paper. Lester Kirschbraun, Evanston, Ill.—1,723,355.

Manufacture of Waterproof Fibrous Products. Harold L. Levin, Nutley, N. J., assignor to Flintkote Company, Boston, Mass. —1,723,361.

Process of Purifying Raw Sugar Juices. Herman Schreiber, Lansing, Mich.—1,724,376.

Paper-Coating Composition. Aaron Ruderman, New York, N. Y.—1,723,581.

Sugar-Crystallizing Apparatus. Bernard H. Varnau and Truman B. Wayne, Sugar Land, Tex.—1,724,627.

Utilization of Sulphite Cellulose Waste Liquor. Wilhelm Michael, Oppau, and Albert Palm, Ludwigshafen-on-the-Rhine, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany.—1,723,800.

Process of Producing Wood Pulp.—William D. Mount, Lynchburg, Va.—1,725,818.

Paper-Making Machine. Alonzo Aldrich, Beloit, Wis.—1,723,834.

Fibrous Material for Odorless Containers. John D. Rue, Madison, Wis.; Sidney D. Wells, Quincy, Ill.; and Francis G. Rawling, Madison, Wis.—1,724,778.

Rubber, Rayon, Synthetic Plastics

Process of Making and Electro-lytically Depositing an Aqueous Rubber Emulsion Containing Sulphur. Samuel E. Sheppard and Leon W. Eberlin, Rochester, N. Y., assignors, by mesne assignments, to American Anode, Inc.—1,723,083.

Process for Preparing Acetone-Soluble, High-Viscosity Cellulose Acetate. Wolfgang Gruber, Burghausen, Oberbayern, Germany, assignor to Dr. Alexander Wacker Gesellschaft für Electrochemische Industrie, Munich, Germany.—1,723,614.

Process of Manufacturing Thioureas. Carl Nelson Hand and Clarence E. Smith, Nitro, W. Va., assignors to Rubber Service Laboratories Co., Akron, Ohio—1,724,580.

Vinyl Ester Resins and Process of Making Same. Howard W. Matheson, Montreal, Quebec, and Frederick W. Skirrow, Shawinigan Falls, Quebec, Canada, assignors to Canadian Electro Products Company, Limited, Montreal, Canada.—1,725,362.

Artificial-Silk Filament and Method of Making Same. James A. Singmaster, Bronxville, N. Y.—1,725,742.

Resin and the Like From Cashew-Nut-Shell Oil. Mortimer T. Harvey, New York, assignor, by direct and mesne assignments, to Harvel Corporation.—1,725,791-7.

Petroleum Refining and Products

Process of Utilizing Petroleum Hydrocarbons. August P. Bjerregaard, Okmulgee, Okla., assignor to Doherty Research Company, New York, N. Y.—1,723,008.

Process of Completely Separating Gasoline From Mineral Oil. Arthur E. Pew, Jr., Bryn Mawr, and Henry Thomas, Ridley Park, Pa., assignors to Sun Oil Company, Philadelphia, Pa.—1,723,368.

Distillation of Hydrocarbon Oils. William W. Holland, Alton, Ill., assignor to Standard Oil Company, Whiting, Ind.—1,723,698.

Pyrogenetic Cracking Process. Richard W. Hanna, Piedmont, Calif., assignor to Standard Oil Company of California, San Francisco, Calif.—1,724,476.

Method of Stabilizing Clay-Treated Oils. George F. Olsen, Los Angeles, Calif., assignor to General Petroleum Corporation of California.—1,724,510.

Revivifying Adsorbent Materials. William M. Stratford, Port Arthur, Tex., assignor to The Texas Company, New York, N. Y.—1,724,531.

Process for Obtaining Solid Paraffin. Johan Frederik Petrus Schönfeld, Hilversum, Netherlands, assignor of one-half to N. V. De Bataafsche Petroleum Maatschappij, The Hague, Netherlands.—1,724,731-2.

Process and Apparatus for the Cracking of Hydrocarbon Oils. George William Gray, New York, N. Y., assignor, by mesne assignments, to The Texas Company, New York, N. Y.—1,724,760.

Process of Treating Cracked Hydro-Carbons. Gustav Egloff and Jacque C. Morrell, Chicago, Ill., assignors to Universal Oil Products Company, Chicago, Ill.—1,725,068.

Method for Cooling the Heating Coils of an Oil-Cracking apparatus. Gustav Egloff and Harry P. Benner, Chicago, Ill., assignors to Universal Oil Products Company, Chicago, Ill.—1,725,067.

Hydrogenerating and Cracking Organization. Milon J. Trumble, Alhambra, Calif.—1,725,320.

Method and Apparatus for Converting Hydrocarbons. Louis J. Walsh, Belmont, Mass., assignor to Standard Oil Development Company.—1,725,434.

Process and Apparatus for Treating Oils. George D. White, Port Arthur, Tex., assignor, by mesne assignments, to The Texas Company, New York, N. Y.—1,726,280.

Coal Products

Illuminating-Gas and Water-Gas Apparatus. Heinrich Koppers, Essen-Ruhr, Germany, assignor to The Koppers Development Corporation.—1,723,279-80.

Process of Separating Hydrogen From Gaseous Mixtures. George Francois Jaubert, Paris, France, assignor to Société Ammonia, Paris, France.—1,723,425.

Process of Obtaining Liquid Products From Coal and the Like. Michael Melamid, Berlin-Zehlendorf, Germany.—1,723,431.

Apparatus for Carbonizing Coal and the Like. Frank C. Greene, Waukegan, Ill., and Irving F. Laucks, Seattle, Wash., assignors to Old Ben Coal Corporation, Chicago, Ill.—1,723,932.

Process for the Recovery of Gas Tars From Emulsions with Water. Russell R. Ripley and Sigmund C. Schwartz, Portland, Oreg.—1,724,222.

Carbureted Water-Gas Apparatus. Robert M. Searle, Rochester, N. Y.—1,726,317.

Process for Obtaining Gases Rich in Ethylene. Hermann Suida, Modling, Austria, assignor to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany.—1,726,048.

Recording Gas Calorimeter. Charles Vernon Boys, Westminster, London, England.—1,726,140.

Organic Processes

Production of Lactic and Acetic Acids. William H. Peterson and Edwin B. Fred, Madison, Wis., assignors to Wisconsin Alumni Research Foundation.—1,723,298.

Process of Chlorination of Methane. Koloman Roka, Constance, Germany, assignor to the Firm of Holzverkohlungs-Industrie Aktiengesellschaft, Constance. Baden, Germany.—1,723,442.

Process of Making Dinitrophenol. Donald B. Bradner, Edgewood, Md., and Frank H. Beall, Newark, N. J.—1,723,761.

Process for Producing Butyl and Isopropyl Alcohols. Alexander Izsak, Central Park, N. J., assignor to Eastern Alcohol Corporation, Wilmington, Del.—1,725,083.

Process of Producing Fusel Oil by Fermentation. Frank A. McDermott, Claymont, Del., assignor to Eastern Alcohol Corporation, Wilmington, Del.—1,725,084.

Process of Manufacturing Carbon. Anton Lederer, Vienna, Austria.—1,725,359.

Production of Glycerin by Fermentation. Frank A. McDermott, Claymont, Del., assignor to E. I. du Pont de Nemours & Company, Wilmington, Del.—1,725,363.

Process of Decolorizing and Refining Crude Cottonseed Oil. Walter S. Baylis, Los Angeles, Calif., assignor, by mesne assignments, to Filtrol Company of California.—1,725,895.

Process for the Manufacture of Gluconic Acid. Horace T. Herrick and Orville E. May, Washington, D. C., assignors to The Government and the People of the United States of America.—1,726,067.

Method of Making Aniline. Joseph W. Britton and William H. Williams, Midland, Mich., assignors to Dow Chemical Company, Midland, Mich.—1,726,170-3.

Inorganic Processes

Production of White Lead. Frank T. Bailey and Wilson Austin, New York, N. Y. —1,723,001.

Method of Manufacturing Black Ash. Zoltan de Horvath, Riverside, Ill., assignor to Eagle Picher Lead Company, Cincinnati, Ohio.—1,723,138.

Aluminum-Plated Article and Process for Producing the Same. Daniel Gray and Richard O. Bailey, Oneida, and William S. Murray, Utica, N. Y., assignors to Oneida Community, Limited, Oneida, N. Y.—1,723-277.

Method of Obtaining Pure Chlorine. David A. Pritchard, Windsor, Ontario, and Jesse H. Hubel, Sandwich, Ontario, Canada, assignors to Canadian Industries, Limited, Montreal, Canada.—1,723,300.

Process of Making Gaseous Mixtures of Nitrogen and Hydrogen. Emil Edwin, Trondhjem, Norway.—1,723,772.

Process for the Production of Phosphorus and Fusion Cement From Natural Phosphates. Wladimer Kyber, Berlin-Steglitz, Germany.—1,723,791.

Art of Refining Borax. Charles F. Ritchie and William A. Gale, Trona, Calif., assignors, by mesne assignments, to American Potash & Chemical Corporation, New York, N. Y.—1,724,420.

Production of Gas Strong in Sulphur Dioxide. George A. Richter, Berlin, N. H., assignor to Brown Company, Berlin, N. H. —1,724,421.

Process for Crystallizing Salts from Brine. George B. Burnham, Reno, Nev., assignor to Burnham Chemical Company, Reno, Nev.—1,724,558.

Manufacture of Ammonium Chloride Crystals. Joseph William Moore, Runcorn, and Wilfrid Gustav Polack, Frodsham, England, assignors to Imperial Chemical Industries Limited, London, England.—1,725,292.

Method of Oxidizing Ammonia. Frans Georg Liljenroth, Stockholm, Sweden.—1,725,462.

Method of Producing Metallic Sulphates. Friedrich Johannsen, Magdeburg-Buckau, Germany, assignor to the Firm Fried. Krupp Grusonwerk Aktiengesellschaft, Magdeburg-Buckau, Germany.—1,725,865.

Process of Purifying Aluminum Oxide. Sven Emil Sieurin and Alfred Sigurd, Edlund, Hoganas, Sweden.—1,726,001.

Electrochemical Treatment of Saline and Alkaline Solutions. Herschel C. Parker, Los Angeles, Calif.—1,726,236.

Process for Concentrating Sulphuric Acid. Walter Howard Simonson, Brooklyn, and Otto Mantius, New York, N. Y.—1,726,321.

Chemical Engineering Processes and Equipment

Combined Feed Device and Magnetic Separator. Orlin S. Anderson, Lakewood, Ohio, assignor to The V. D. Anderson Company, Cleveland, Ohio.—1,723,119.

Impregnation and Drying Apparatus. Horace M. Eaton, Lynn, Mass., assignor, by mesne assignments, to Norman Edmunds, Swampscott, Mass.—1,723,336.

Method of Preserving Wood. Walter O. Snelling, Allentown, Pa.—1,723,384.

Tanning. Frank S. Low, Niagara Falls, N. Y.—1,723,568.

Coating Composition and Method of Making the Same. Charles M. Stine and Cole Coolidge, Wilmington, Del., assignor to E. I. du Pont de Nemours & Company, Wilmington, Del.—1,723,632.

Fractionating Condenser. David T. Williams, Paterson, N. J.—1,723,637.

Still Construction. William H. Pavitt, Brooklyn, N. Y., assignor, by mesne assignments, to Wilputte Coke Oven Corporation, New York, N. Y.—1,723,657.

Apparatus for Pulverizing Materials. William T. Doyle, Boston, Mass., assignor to Sturtevant Mill Company, Boston, Mass. —1,723,726.

Kiln. William D. Mount, Lynchburg, Va., and Irving Warner, Wilmington, Del.—1,725,763.

Apparatus for Applying Waterproofing Material to Sheets. Lester Kirschbraun, Chicago, Ill., and Chester R. MacDonald, Middletown, Ohio; said MacDonald assignor to Flintkote Company, Boston, Mass.—1,724,137.

Pump and Like Device for Controlling the Rate of Delivery of Fluids. Ernest Lunge, London, England, assignor to Courtaulds, Limited, London, England.—1,723,874-5.

Separator. Harold M. Plaisted, St. Louis, Mo.—1,724,041.

Thickener. Ernest J. Sweetland, Hazleton, Pa., assignor to Oliver United Filters, Inc., San Francisco, Calif.—1,724,436.

High-Speed Mixer. Robert M. Greenleaf and Orville L. Routt, Los Angeles, Calif., assignors to Plastoid Products, Inc., Los Angeles, Calif.—1,725,186.

Felted Waterproof Composition and Process of Making Same. Lester Kirschbraun, Chicago, Ill.—1,725,645-7.

Emulsion Product. Lester Kirschbraun, Leonia, N. J.—1,725,648.

Apparatus and Method for Treating Finely Divided Solids. Vernor S. Henry, Summit; Arthur Wright, Upper Montclair, and Frank W. Young, Verona, N. J., assignors to Filtration Engineers, Inc., New York, N. Y.—1,726,511.

NEWS *of the Industry*

Twelve Hundred at A.C.S. Minneapolis Meeting

TWELVE hundred members and guests participated in the Minneapolis meeting of the American Chemical Society, which was held Sept. 9-13, with the Minnesota Section as hosts. At the meeting of the Council, in addition to the usual routine business, three matters of general interest were considered: First, a resolution was adopted urging the change in name of the Chemical Warfare Service to the Chemical Corps of the U. S. Army; second, a committee of five prominent chemists was appointed to develop means by which the aid of the society could be made readily available to those who wish to endow or aid financially in chemical research; and third, a special committee was named to make a survey of the business affairs of the society and to recommend any changes which may be needed in the constitution, by-laws, or methods in order to render the work more efficient.

Supplementing the scientific sessions and social gatherings of the week were numerous industrial-plant trips, including visits to works of Armour & Company, Archer-Daniels-Midland Company, Ford Motor Company and several food-processing plants making flour, ice cream, and dairy products. At the close of the meetings in Minneapolis about one hundred members formed a party to visit Duluth and Cloquet, Minn. At the last-named place the party were guests of the Weyerhauser interests, which operate a complete lumber and wood products business, including pulp and paper mills, and the Wood Conversion Company plant, which makes balsam wool, wall board, and other byproducts of wood.

The general meeting of the society included a presidential address by Irving Langmuir on "Modern Concepts in Physics and Their Relation to Chemistry" and the formal presentation of the 1929 Priestley Medal for distinguished services to chemistry to Francis P. Garvan.

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Chemical Apparatus to Be Exhibited in Germany

ACHEMA VI, an exposition for the Chemical Apparatus Industry of Germany, will be held at Frankfort-on-Main, June 10 to 22, 1930, and during the progress of the exposition the annual convention of the Association of German Representatives of the Chemical Industry will be in session.

This exposition is one of the outstanding events in Germany and especially in Frankford-on-Main, the greatest chemical industry center in the world.

Three years will have elapsed since the last exposition, held in Essen in 1927, and the representatives of the German chemical industry are putting forth every effort to makke this jubilee, or tenth anniversary exposition, a memorable tribute to the science and its recent achievements.

During the progress of the exposition numerous conventions will be in session at Frankfort-on-Main, among them the German Association of Chemical Apparatus Manufacturers, the Society of German Chemical Engineers, the Association of German Institutes for the Construction of Apparatus, the German Association for the Chemical Apparatus Industry, the German Rubber Association, a scientific association of chemical and rubber engineers, and many others.

Manufacturers and others desiring to exhibit may communicate with the American representative of Achema VI, the International Exposition Co., Grand Central Palace, New York City.

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Symposia Planned for Fall Meeting of T.A.P.P.I.

ON SEPT. 24, the fall meeting of the Technical Association of the Pulp and Paper Industry will open at the Hotel Jefferson, Richmond, Va. The general meeting will be conducted by P. H. Glatfelter and will be followed by papers on "What Is Patentable in Paper Making," by C. W. Rivise, and "Slitters and Winders," by J. A. Cameron. On Sept. 25 a symposium on pulp evaluation will be held, with D. E. Cable as chairman. The papers will include "Modern Recovery Practice," by C. L. Wagner; "A New Sectional Speed Regulator for Sectional Paper Machine Drive," by R. R. Baker; "Pulp Testing," by H. C. Bradford; "The Beater Method of Evaluating Pulp," by H. A. Rothchild, and "Estimating Pulp Quality," by J. E. O'Connell. B. W. Scribner will conduct a symposium on paper standards on Sept. 26. M. B. Shaw will present a paper on "Paper-Making Research" and F. T. Carson will discuss "Paper Standards." A shrinkage symposium conducted by Allen Abrams will be featured by papers on "Domestic Clays for Coating and Loading," by O. W. Callighan; "Shrinkage," by A. T. Taylor, and "Shrinkage Reduction," by D. K. Pattillo.

H. S. Fox Will Discuss British Chemical Demands

WITH the idea of giving the chemical industry in the South the benefit of his knowledge of the consuming market in the United Kingdom, Homer S. Fox, assistant commercial attaché of the Department of Commerce stationed at London, has spent most of September and will spend the first half of October in a tour through the South which will include such centers as Charleston, Savannah, Brunswick, Jacksonville, Tampa, Pensacola, Atlanta, Birmingham, New Orleans, Houston, Galveston, Tulsa, Bartlesville and Louisville. On his return Mr. Fox will make a Northern trip to include Baltimore, Wilmington, Philadelphia, New York, Bridgeport, Boston, Buffalo, Cleveland, Detroit, Chicago, Kansas City, St. Louis and Indianapolis.

Mr. Fox is pointing out that the British are making great progress with their chemical industry and have developed one of the most important markets for such American commodities. In fact, the sale of American chemicals in the United Kingdom is twice the prewar volume and accounts for one-seventh of its foreign sales. He also points out that England is a great distribution center and that much continental business can be secured by way of the British Isles.

The British are watching chemical development in the South closely, Mr. Fox points out. The rapid growth of the rayon industry, the construction of new phosphoric-acid, aluminum-chloride and carbon-black plants, as well as the proposal of the American I G to set up a thirty million dollar industry in the Monroe gas field of Louisiana, all have been factors in convincing the British that the South as a chemical center will be much to the fore during the next decade and that they have much in common with that development.

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Kuhlmann Votes to Increase Capital Stock

REPORTS from Paris state that shareholders of Etablissements Kuhlmann, manufacturers of chemical products, have authorized an increase in capital of the company to 312,500,000 francs from 300,000,000 francs, by issue of 50,000 ordinary shares of 250 francs nominal value at 725 francs each. They also approved eventual increase in capital to 400,000,000 francs. The immediate increase is for the purpose of absorbing a small French company.

British Chemical Company Plans to Expand

IMPORTANT developments are now under consideration by Imperial Chemical Industries, Ltd. Plans are being completed for an extension in South America, which is regarded as one of the most potentially valuable markets for chemicals in the world. It is probable that Imperial Chemical Industries will decide very shortly on the erection of a large plant in Buenos Aires. This plant will be mainly for the manufacture of tartaric acid and will utilize raw materials from the wine-growing districts of Mendoza and San Juan.

Following the completion of this plant, it is probable that a number of other chemical manufacturing plants will be built in the Argentine by the combine. The Argentine market is in itself extremely valuable, while it also forms a good center for manufacture for the rest of South America.

Imperial Chemical Industries is also making an important extension in the United Kingdom. Its subsidiary, Synthetic Ammonia and Nitrates, Ltd., has now concluded the purchase from William Grey & Co., of West Hartlepool, of land, harbor rights, and a loading wharf on the River Tees. This will greatly improve transport arrangements from the Billingham works. The company's own ships will now load direct at the wharf.

It is reported that Imperial Chemical Industries, Ltd., has appointed an executive board to control the three constituent undertakings of the company on Tees-side. These are Synthetic Ammonia and Nitrates, Ltd., Casebourne and Company, and the Tees Salt Company.

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American Loan for German Nitrogen Company

FUNDS in the form of a loan of $3,000,000 advanced by an American bank in association with German banks to the Ruhr Chemie A. G. of Essen, Germany, will be used to double the company's fixed nitrogen production, the American trade commissioner at Berlin informed the Department of Commerce Sept. 3. The company, formerly the Kohl Chemie, borrowed $8,000,000 in 1928.

Rhur Chemie started production in May, 1929, with its new nitrogen fixation plant at Sterkrade-Holten, operating a Casale ammonia synthesis utilizing waste coke-oven gas hydrogen.

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Sodium Phosphate Imports Reach Large Total

IMPORTS of sodium phosphate into the United States, which have risen steadily since 1923, continued upward during the first half of 1929. Less than 900 tons was imported during 1923; in 1928 European manufacturers sold over 9,800 tons in the United States. During the first half of 1929 the quantity imported for consumption reached 5,029 tons, as compared with 4,162 in the corresponding period of 1928. The official import statistics do not show separately the different types of sodium phosphates imported. It is understood that the bulk of the imports comprise dibasic. Domestic production is chiefly of tribasic salt, while dibasic and monobasic are of minor importance. The latest production statistics, covering operations during 1927, placed the domestic output at 75,000 tons, more than double that of 1923.

An analysis of the imports during the first half of 1929 reveals that the principal source of supply was Germany and the chief entry district was New York. Imports by countries of origin and customs districts are shown in the following table:

Countries	Tons	Districts	Tons
Germany	2,816	New York	4,270
Netherlands	1,143	Philadelphia	338
Belgium	1,059	Massachusetts	290
France	11	Maryland	45
		Virginia	38
		New Orleans	37

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Reduction Asked on Chlorine Freight Rating

THE Mathieson Alkali Works, Inc., New York, has filed a complaint with the Interstate Commerce Commission asking for a reduction from fourth to fifth class in the tank carload rating on liquefied chlorine subject to the present minimum of 30,000 lb. In support of its petition for a lower rating the company represents that since the fourth class rating was applied the development of new industrial uses for chlorine has created a widespread and increasing demand, while quantity production has reduced its value to a small fraction of that prevalent when tank cars were first put on and this service was offered at fourth class rates.

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California Leads In Casein Production

PRODUCTION of casein in the United States during 1928 reported to the Department of Commerce by 140 factories amounted to 22,151,000 lb., of which nearly one-third (7,053,000 lb.) was manufactured in California. One-fourth (4,936,000 lb.) was manufactured in the State of New York, and one-fourth (4,966,000 lb.) in Wisconsin. Vermont, Illinois, and Idaho produced respectively 2,111,000 lb. 697,000 lb., and 633,000 lb.

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Helium Found in Colorado

Discovery of natural gas containing a large proportion of helium is reported at Thatcher, Colo. At a depth of about 900 ft. a well being drilled there found a volume of gas estimated at 3,000,000 cu.ft. daily, of which helium content was reported to be 210,000 cu.ft.

A helium plant, erected near Dexter, Kansas, some years ago by the government, is being moved to Thatcher.

Electrochemists in Session at Pittsburgh

AS *Chem. & Met.* goes to press the American Electrochemical Society is holding its fifty-sixth meeting in Pittsburgh. The meeting was scheduled to open on Sept. 19 with a technical session on "Contributions of Electrochemistry to Aeronautics." On the following day two sessions were planned, one under the auspices of the Electrothermic Division with H. M. St. John presiding, and the other on miscellaneous papers with Francis C. Frary in charge. On Sept. 21 also two sessions were scheduled. Trips were made to numerous plants in Pittsburgh and vicinity.

❖

Canadian Sodium Sulphate Plant Burned

THE sodium sulphate work at Mossbank, Saskatchewan, about 30 miles south of Moose Jaw, have been destroyed by fire, with a loss said to exceed $500,000. More than 500 tons of refined sodium sulphate was ruined. The machinery, which is of a specialized type, is said to be completely destroyed, and the power house and storage houses also are in ruins. The plant was erected in 1921 after the company had spent several hundred thousand dollars in experiments with the glanbers salts deposits in the lake at Mossbank. The deposit is said to be 14 ft. deep, and after eight years of work it is claimed that there has been hardly any impression made on it.

❖

Dutch and German Rayon Companies Merged

ALGEMEENE Kunstzijde Unie (General Rayon Union) has been registered as a limited company to take over entire share capital of Nederlandsche Kunstzijdefabrik-Enka, at Arnhem, Holland, and Vereinigte Glanzstoff-fabriken at Elberfeld, Germany.

The report from Amsterdam states that statutory capital is fixed at 230,048,000 florins, consisting 48,000 florins in preferred shares, 30,000,000 in cumulative preferred and 200,000,000 in common, all of nominal value 1,000 florins. Of this capital, 46,048,000 florins are now subscribed.

❖

Mitsui Will Enlarge Japanese Indigo Production

ENCOURAGED by the government's definite policy of assisting the artificial indigo industry, the Mitsui Mining Company has decided to expand its dyestuff enterprise now carried on by the Mitsui Dyestuffs Manufactory. It will make alizarine and sulphur color as well as artificial indigo. The firm intends to increase its capital to 7,000,000 yen and after four or five years expects to turn out annually something like 1,000 tons of synthetic indigo (present output 50 tons a year), which is the amount of the total demand of the country.

Linseed Oil Prices Advance Sharply

OUTSTANDING among developments last month in the market for chemicals and related products was the marking up of prices for linseed oil. On Sept. 9 the official report was issued showing condition of the domestic flaxseed crop as of Sept. 1. The indicated outturn was placed 16,388,000 bu. In the July report the probable yield was given at 19,900,000 bu. The August report reduced this to 18,000,000 bu.

The steady deterioration as indicated in the September report had the effect of moving up prices for flaxseed in the Duluth market. This was followed by reports that the Argentine crop was suffering from lack of moisture. The Buenos Aires market then staged a sensational advance which had a corresponding effect on domestic markets. Reduced to its simplest terms, the domestic crop of flaxseed this year will fall short of filling home needs by close to 30,000,000 bu. Damage to the Argentine crop will reduce the exportable surplus there and thus increase prices. The effect on the linseed oil market may be seen by reference to the quotation of 12.8c. per lb., which obtained a month ago and the asking price of 15.8c. per lb. which prevailed on Sept. 14.

In this connection it is important to note that consumption of linseed oil in this country during the second quarter of this year amounted to more than 249,000,000 lb., as against a production of 184,087,611 lb. Stocks on hand consequently were reduced, so that the supply on hand at factories and warehouses on July 1 was about 123,000,000 lb., or about 68,000,000 lb. lower than the supply on hand at the corresponding period of last year. The stocks held on July 1 this year were lower for that date than has been the case since 1924.

CHIEF interest in chemical products is now centered in the new contract prices which are soon expected and which will apply to deliveries over 1930. It was rumored that 1930 contracts already have been written in some cases and at prices slightly lower than those quoted for 1929 deliveries. No open prices, however, have been named, and it is generally held that mineral acids, alkalis, and ammonia will not be subject to price changes.

Contract deliveries of chemicals have been going forward in large volume and take up the greater part of production. Since the turn of the month there has been an increase in inquiry for additional supplies and a larger turnover has taken place in the spot market.

Synthetic methanol has been unstable in price for some time and sales were made at private terms with competition among producers creating a situation favorable to buyers. At the close of the period the price weakness was less apparent and sellers appeared to be making an effort to stabilize quotations. Figures for production of methanol from wood distillation were recently issued and give the output for the first half of this year as 4,828,883 gal., as compared with 4,389,445 gal. for the corresponding period of 1928.

Chem. & Met. Weighted Index of Prices for Oils and Fats

Base = 100 for 1913-14

This month	**129.19**
Last month	123.06
September, 1928	121.01
September, 1927	134.48

The weighted index number advanced sharply during the month. Rises in values for linseed oil were chiefly responsible. Crude menhaden oil closed at an advance and cottonseed oil was steadied by the low crop estimate for cotton.

Chem. & Met. Weighted Index of Chemical Prices

Base = 100 for 1913-14

This month	**112.37**
Last month	112.37
September, 1928	113.02
September, 1927	112.55

While some of the small-tonnage chemicals underwent price changes during the month, the more important selections were maintained on a steady basis and the weighted index number was unchanged.

Wider Markets for Metals

IN HIS speech before the British Association for the Advancement of Science, the president of that organization placed special stress on the rapid increase in the world consumption of metals. As an illustration he pointed out that in 1870 the United States produced 69,000 tons of steel; in 1880, 1,250,000 tons; in 1890, 4,250,000 tons; in 1900, 10,000,000 tons; and in 1928, 45,000,000 tons. Reference to figures of production shows that the domestic output of other metals likewise has increased rapidly in recent years.

Despite the larger tonnage of metals which is now going into consumption, market prices have been held on a fairly stable basis with exceptions found when the supply began to fall below demand. The flurry in the copper market last year is a case in point. Incidentally, the sale of copper in the week ended Sept. 4 was the largest for any week in the history of the domestic industry. The trend is toward higher prices, but some large producers are opposing advances on the ground that stabilized prices will work for the betterment of all.

Producers of lead are well sold ahead and the market is in a strong position with any revisions in price favoring the up side. Silver has weakened considerably in the last two weeks with selling pressure in China as the disturbing factor. Stocks of tin at the close of August showed a gain of 2,600 tons over the preceding month and the market sold off as a result. Zinc has been quiet but shows a steady price trend.

Following will be found a tabulation of prices for metals and alloys of most interest to the chemical engineer. They are presented here primarily to give the reader an idea of the approximate price relations existing among the various construction materials. In the case of metals the quotations represent either the prices as quoted in the New York Metal Exchange or the figures named by controlling producers. The prices are corrected as of Sept. 14. In the case of alloys, the quotations represent the base-price of producers as applied to deliveries over the last month. They are in some instances subject to discounts, in other instances the quoted base prices will be increased according to the specifications of buyers. In general, prices for alloys vary according to quantity, pattern, equipment and design.

Current Prices for Specified Metals and Alloys

	Base Price Per lb.
Adnic, 2 to 8 in., wide	$0.75
Advance	1.30-80.00
Alcumite, 1½ in. rounds	.58
Alcumite, ¾ in. rounds	.65
Blackor	15.00
Carpenter stainless steel, No. 1	.20
Carpenter stainless steel, No. 2	.37
Carpenter stainless steel, No. 3	.25
Carpenter stainless steel, No. 4	.28
Carpenter stainless steel, No. 5	.20
Comet	1.60- 2.00
Cristite	3.50
Cromin D	1.60-22.00
Cupron	1.30-80.00
Dowmetal	.80- 1.00
Durimet A, sheets	.45
Durimet A, bars	.38
Durimet B, sheets	.50
Durimet B, bars	.43
Enduro AA, bars	.25
Enduro AA, plates	.25
Enduro AA, sheets	.32
Enduro S, bars	.20
Enduro S, plates	.20
Enduro S, sheets	.32
Enduro S-15, bars	.20
Enduro KA2, bars	.28
Enduro KA2, plates	.31
Enduro KA2, sheets	.35
Illium	1.90
Lucero	1.29- 9.49
Manganin	1.97- 21.33
Nichrome	2.70- 95.00
Nichrome IV	4.05-142.00
Plmite	2.75
Pyrasteel	.45
Sweetaloy, 16-19	.55-.85
Sweetaloy, 20-22	.65-.95
Tophet A	4.05-360.00
Tophet C	2.70-240.00

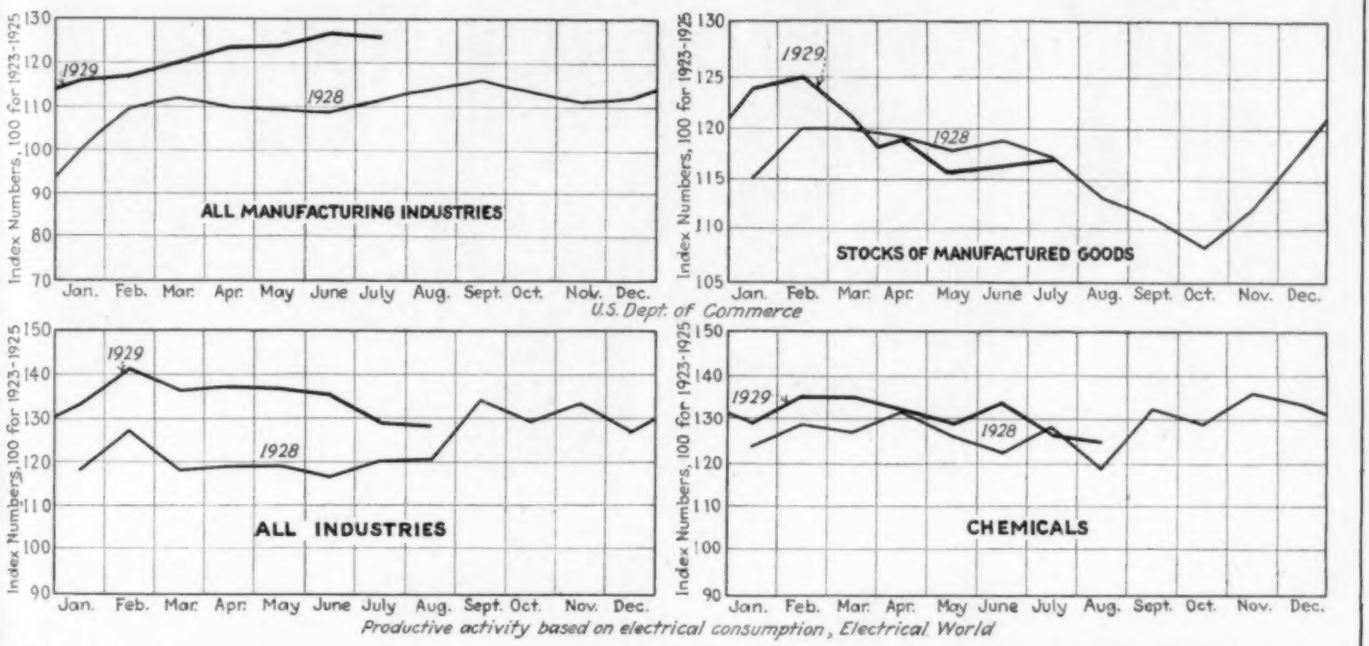
Ferro-Alloys

Ferrotitanium, 15-18%	ton	$200.00
Ferromanganese, 78-82%	ton	105.00
Spiegeleisen, 19-21%	ton	33.00
Ferrosilicon, 14-17%	ton	45.00
Ferrotungsten, 70-80%	lb.	1.35
Ferro-uranium, 35-50%	lb.	4.50
Ferrovanadium, 30-40%	lb.	3.15

Non-Ferrous Metals

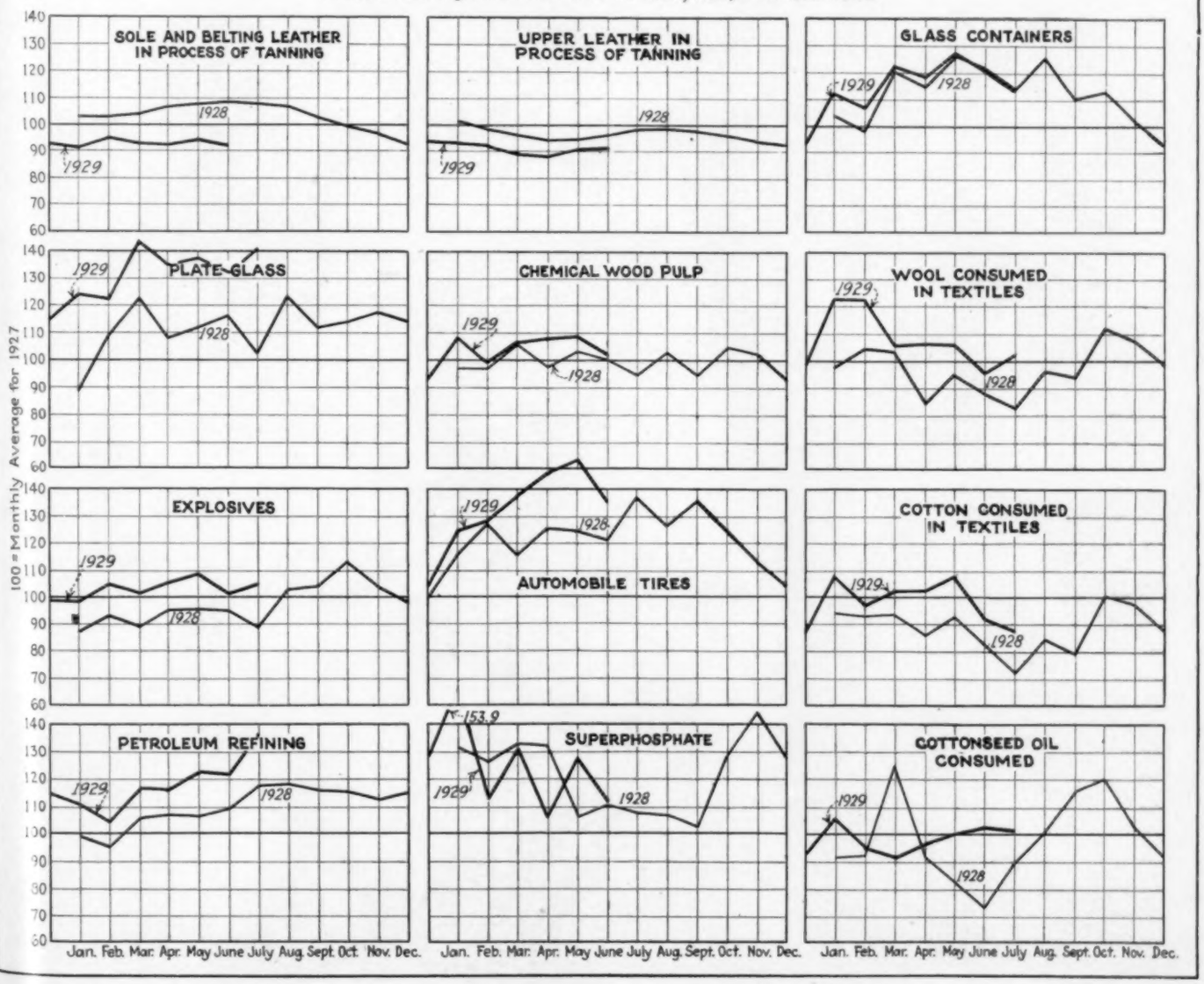
Copper, electrolytic	lb.	.18
Aluminum, 96-99%	lb.	.243
Antimony, Chin. and Jap.	lb.	.08-.08½
Nickel, 99%	lb.	.35
Monel metal, blocks	lb.	.28
Tin, Straits	lb.	.45½
Lead, New York, spot	lb.	.06⁰
Zinc, New York, spot	lb.	.07¼
Silver, commercial	oz.	.50½
Cadmium	lb.	.80-.90
Bismuth, ton lots	lb.	1.70
Cobalt	lb.	2.50
Magnesium, ingots, 99%	lb.	.85-1.10
Platinum, ref	oz.	64.00-66.00
Palladium, ref	oz.	38.00-40.00
Tungsten, powder	lb.	1.35- 1.50

ACTIVITY IN PRODUCING AND CONSUMING INDUSTRIES



U.S. Dept. of Commerce

Productive activity based on electrical consumption, Electrical World



CURRENT PRICES *in the* NEW YORK MARKET

For Chemicals, Oils and Allied Products

The following prices refer to round lots in the New York Market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to September 14.

Industrial Chemicals

		Current Price	Last Month	Last Year
Acetone, drums	lb.	$0.14 -$0.15	$0.14 -$0.15	$0.14 -$0.15
Acid, acetic, 28%, bbl.	cwt.	3.88 - 4.03	3.88 - 4.03	3.62½ - 3.87½
Boric, bbl.	lb.	.05¾- .06	.05½- .06	.06½- .07
Citric, kegs	lb.	.46 - .47	.46 - .47	.46 - .47
Formic, bbl.	lb.	.10½- .11	.10½- .11	.11 - .12
Gallic, tech., bbl.	lb.	.50 - .55	.50 - .55	.50 - .55
Hydrofluoric 30% carb.	lb.	.06 - .07	.06 - .07	.06 - .07
Lactic, 44%, tech., light, bbl.	lb.	.11 - .11½	.11 - .11½	.12 - .12½
22%, tech., light, bbl.	lb.	.05½- .06	.05½- .06	.05½- .06
Muriatic, 18°, tanks	cwt.	.85 - .90	.85 - .90	.85 - .90
Nitric, 36°, carboys	lb.	.05 - .05½	.05 - .05½	.05 - .05½
Oleum, tanks, wks.	ton	18.00 -20.00	18.00 -20.00	18.00- 20.00
Oxalic, crystals, bbl.	lb.	.11 - .11½	.11 - .11½	.11 - .11½
Phosphoric, tech., c'bys.	lb.	.08½- .09	.08½- .09	.08½- .09
Sulphuric, 60°, tanks	ton	11.00 -11.50	11.00 -11.50	11.00 -11.50
Tannic, tech., bbl.	lb.	.35 - .40	.35 - .40	.35 - .40
Tartaric, powd., bbl.	lb.	.38 - .39	.38 - .39	.38 - .39
Tungstic, bbl.	lb.	1.30 - 1.40	1.30 - 1.40	1.00 - 1.20
Alcohol, ethyl, 190 p'f., bbl.	gal.	2.68½- 2.71	2.68½- 2.71	2.68½- 2.71
Alcohol, Butyl, dr.	lb.	.16½- .17	.16½- .17	.18½- .19
Denatured, 190 proof				
No. 1 special dr.	gal.	.51 -.....	.51 -.....	.47 -.....
No. 5, 188 proof, dr.	gal.	.51 -.....	.51 -.....	.47 -.....
Alum, ammonia, lump, bbl.	lb.	.03½- .04	.03½- .04	.03½- .04
Chrome, bbl.	lb.	.05½- .05¾	.05½- .05¾	.05½- .06
Potash, lump, bbl.	lb.	.03 - .03½	.03 - .03½	.02½- .03½
Aluminum sulphate, com., bags	cwt.	1.40 - 1.45	1.40 - 1.45	1.40 - 1.45
Iron free, bg.	cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Aqua ammonia, 26°, drums	lb.	.03 - .04	.03 - .04	.03 - .04
Ammonia, anhydrous, cyl.	lb.	.14 -.....	.14 -.....	.13½-.....
Ammonium carbonate, powd., tech., casks	lb.	.12 - .13	.12 - .13	.12 - .13
Sulphate, wks.	cwt.	2.10 -.....	2.10 -.....	2.40 -.....
Amylacetate tech., drums	gal.	1.75 - 2.00	1.75 - 2.00	1.75 - 2.00
Antimony Oxide, bbl.	lb.	.09 - .10	.09 - .10	.09 - .10
Arsenic, white, powd., bbl.	lb.	.04 - .04½	.04 - .04½	.04 - .04½
Red, powd., kegs	lb.	.09 - .10	.09 - .10	.09 - .10
Barium carbonate, bbl.	ton	58 00 -60 00	58 00 -60 00	57.50 -60 00
Chloride, bbl.	ton	65.00 -67 00	65.00 -67.00	63.00 -70.00
Nitrate, cask	lb.	.07½- .08	.07½- .08	.08 - .08½
Blanc fixe, dry, bbl.	lb.	.03½- .04	.03½- .04	.04 - .04½
Bleaching powder, f.o.b., wks., drums	cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Borax, bbl.	lb.	.02½- .03	.02½- .03	.02½- .03
Bromine, cs.	lb.	.45 - .47	.45 - .47	.45 - .47
Calcium acetate, bags	cwt.	4.50 -.....	4.50 -.....	4.00 -.....
Arsenate, dr.	lb.	.07 - .10	.06½- .07	.06½- .07
Carbide drums	lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., wks.	ton	20.00 -.....	20.00 -.....	20.00 -.....
Phosphate, bbl.	lb.	.08 - .08½	.08 - .08½	.07 - .07½
Carbon bisulphide, drums	lb.	.05 - .06	.05 - .06	.05 - .06
Tetrachloride drums	lb.	.06½- .07	.06½- .07	.06½- .07
Chlorine, liquid, tanks, wks.	lb.	.03 - .03½	.03 - .03½	.03½- .04½
Cylinders	lb.	.05 - .08	.05 - .08	.05½- .08
Cobalt oxide, cans	lb.	2.10 - 2.20	2.10 - 2.20	2.10 - 2.25
Copperas, bgs., f.o.b. wks.	ton	15.00 -16.00	15.00- 16.00	16.00 -17.00
Copper carbonate, bbl.	lb.	.22 - .23	.22 - .23	.17 - .18
Cyanide, tech., bbl.	lb.	.49 - .50	.49 - .50	.49 - .50
Sulphate, bbl.	cwt.	6.00 - 6.10	6.00 - 6.10	5.30 - 5.50
Cream of tartar, bbl.	lb	.26 - .26½	.26 - .26½	.26½- .27
Diethylene glycol, dr.	lb.	.10 - .15	.10 - .15	.10 - .15
Epsom salt, dom., tech., bbl.	cwt.	1.75 - 2.15	1.75 - 2.00	1.75 - 2.00
Imp., tech., bags	cwt.	1.15 - 1.25	1.15 - 1.25	1.15 - 1.25
Ethyl acetate, drums	gal.	1.10 -.....	1.10 -.....	.83 -.....
Formaldehyde, 40%, bbl.	lb.	.08½- .09	.08½- .09	.08½- .09
Furfural, dr.	lb.	.15 - .17½	.15 - .17½	.15 - .17
Fusel oil, crude, drums	gal.	1.30 - 1.40	1.30 - 1.40	1.30 - 1.40
Refined, dr.	gal.	1.90 - 2.00	1.90 - 2.00	2.50 - 3.00
Glaubers salt, bags	cwt.	1.10 - 1.20	1.10 - 1.20	1.00 - 1.10
Glycerine, c.p., drums, extra.	lb.	.13½- 14½	.13½- .14½	.14 - .15
Lead:				
White, basic carbonate, dry, casks	lb.	.09 -.....	.09 -.....	.08½-.....
White, basic sulphate, sck.	lb.	.08½-.....	.08½-.....	.07½-.....
Red, dry, sck.	lb.	.10 -.....	.10½-.....	.09½-.....
Lead acetate, white crys., bbl.	lb.	.14 - .14½	.14 - .14½	.13 - .13½
Lead arsenate, powd., bbl.	lb.	.13 - .14	.13 - .14	.12 - .13
Lime, chem., bulk	ton	8.50 -.....	8.50 -.....	8.50 -.....
Litharge, pwd., csk.	lb.	.09½-.....	.09½-.....	.08½-.....
Lithopone, bags	lb.	.05½- .06	.05½- .06	.05½- .06½
Magnesium carb., tech., bags	lb.	.06 - .06½	.06 - .06½	.06½- .07
Methanol, 95%, dr.	gal.	.55 -.....	.55 -.....	.55 -.....
97%, dr.	gal.	.55 -.....	.55 -.....	.55 -.....
Nickel salt, double, bbl.	lb.	.13 - .13½	.13 - .13½	.10 - .11
Single, bbl.	lb.	.13 - .13½	.13 - .13½	.10½- .11½
Orange mineral, csk.	lb.	$0.12½-.....	$0.12½-.....	$0.11½-.....
Phosphorus, red, cases	lb.	.55 - .57	.55 - .57	.62 - .65
Yellow, cases	lb.	.32 - .33	.32 - .34	.32 - .33
Potassium bichromate, casks.	lb.	.08½- .08¾	.08½- .08¾	.08½- .08¾
Carbonate, 80-85%, calc., csk.	lb	.05½- .06	.05½- .06	.05½- .06
Chlorate, powd.	lb.	.07½- .08¼	.07½- .08¼	.06½- .07
Cyanide, cs.	lb.	.52 - .55	.52 - .55	.51 - .53
First sorts, csk.	lb.	.08¾- .09	.08¾- .09	.08¾- .09
Hydroxide(c'stic potash) dr.	lb.	.07½- .07¾	.07½- .07¾	.07½- .07¾
Muriate, 80% bgs.	ton	36.75 -.....	36.75 -.....	36.40 -.....
Nitrate, bbl.	lb.	.06 - .06½	.06 - .06½	.06 - .07½
Permanganate, drums	lb.	.16 - .16½	.16 - .16½	.15 - .16
Prussiate, yellow, casks	lb.	.19 - .19½	.19 - .19½	.18 - .19
Sal ammoniac, white, casks.	lb.	.046- .05	.046- .05	.047- .05
Salsoda, bbl.	cwt.	.90 - .95	.90 - .95	.90 - .95
Salt cake, bulk	ton	18.00 - 19.00	16.00 -18.00	14.00 -17.00
Soda ash, light, 58%, bags, contract	cwt.	1.32 -.....	1.32 -.....	1.32 -.....
Dense, bags	cwt.	1.35 -.....	1.35 -.....	1.35 -.....
Soda, caustic, 76%, solid, drums, contract	cwt.	2.90 - 3.00	2.90 - 3.00	3.00 - 3.10
Acetate, works, bbl.	lb.	.06½- .07	.05 - .05¾	.05½- .06
Bicarbonate, bbl.	cwt.	2.00 - 2.25	2.00 - 2.25	2.00 - 2.25
Bichromate, casks	lb.	.07 - .07½	.07 - .07½	.07 - .07½
Bisulphate, bulk	ton	12.00 -15.00	12.00 -15.00	3.00 - 3.50
Bisulphite, bbl.	lb.	.03½- .03¾	.03½- .03¾	.03¾- .04
Chlorate, kegs	lb.	.07 - .07½	.07 - .07½	.06½- .06¾
Chloride, tech.	ton	12.00 -14.75	12.00- 14.75	12.00 -14.00
Cyanide, cases, dom.	lb.	.18 - .22	.18 - .22	.18 - .22
Fluoride, bbl.	lb.	.08½- .09¼	.08½- .09¼	.08½- .09
Hyposulphite, bbl.	lb.	2.50 - 3.00	2.50 - 3.00	2.50 - 3.00
Nitrate, bags	cwt.	2.10 -.....	2.10 -.....	2.15 -.....
Nitrite, casks	lb.	.07½- .08	.07½- .08	.07½- .08
Phosphate, dibasic, bbl.	lb.	.03½- .03¾	.03½- .03¾	.03¾- .03¼
Prussiate, yel. drums	lb.	.11½- .12	.11½- .12	.11½- .12
Silicate (30°, drums)	cwt.	.75 - 1.15	.75 - 1.15	.75 - 1.15
Sulphide, fused, 60-62%, dr.	lb.	.02¾- .03¼	.02¾- .03	.03¼- .04
Sulphite, crys., bbl.	lb.	.02¾- .03	.02½- .03	.02½- .03
Strontium nitrate, bbl.	lb.	.09 - .09¼	.09 - .09¼	.09 - .09¼
Sulphur, crude at mine, bulk.	ton	18.00 -.....	18.00 -.....	18.00 -.....
Chloride, dr.	lb.	.04 - .05	.04 - .05	.04 - .05
Dioxide, cyl.	lb.	.09 - .10	.09 - .10	.09 - .10
Flour, bag	cwt.	1.55 - 3.00	1.55 - 3.00	1.55 - 3.00
Tin bichloride, bbl.	lb.	.14½-.....	.14¾-.....	.14¾-.....
Oxide, bbl.	lb.	.53 -.....	.53 -.....	.53 -.....
Crystals, bbl.	lb.	.35½-.....	.35 -.....	.37 -.....
Zinc chloride, gran., bbl.	lb.	.06½- .06¾	.06½- .06¾	.06½- .06¾
Carbonate, bbl.	lb.	.10½- .11	.10 - .10½	.10 - .11
Cyanide, dr.	lb.	.40 - .41	.40 - .41	.40 - .41
Dust, bbl.	lb.	.08½- .09	.08¾- .09	.09 - .10
Zinc oxide, lead free, bag.	lb.	.06½-.....	.06½-.....	.06½-.....
5% lead sulphate, bags	lb.	.06½-.....	.06½-.....	.06½-.....
Sulphate, bbl.	cwt.	3.50 - 3.75	2.75 - 3.00	2.75 - 3.00

Oils and Fats

		Current Price	Last Month	Last Year
Castor oil, No. 3, bbl.	lb.	$0.13½-$0.14	$0.13½-$0.14	$0.13½-$0.14
Chinawood oil, bbl.	lb.	.14 -.....	.14½-.....	.14½-.....
Coconut oil, Ceylon, tanks, N. Y.	lb.	.06¾-.....	.06¾-.....	.08½-.....
Corn oil crude, tanks, (f.o.b. mill)	lb.	.08½-.....	.07¾-.....	.08¾-.....
Cottonseed oil, crude (f.o.b. mill), tanks	lb.	.07¾-.....	.07¾-.....	.08 -.....
Linseed oil, raw, car lots, bbl.	lb.	15 8 -.....	.128-.....	.096-.....
Palm, Lagos, casks	lb.	.07½-.....	.07¾-.....	.07¾-.....
Niger, casks	lb.	.07½-.....	.07½-.....	.07½-.....
Palm Kernel, bbl.	lb.	.08½-.....	.08½-.....	.09½-.....
Peanut oil, crude, tanks (mill)	lb.	.08½-.....	.08½-.....	.08¾-.....
Rapeseed oil, refined, bbl.	gal.	.80 - .82	.80 - .82	.88 - .90
Soya bean tank (f.o.b. Coast)	lb.	.09½-.....	.09½-.....	.09½-.....
Sulphur (olive foots), bbl.	lb.	.09 -.....	.09 -.....	.09½-.....
Cod, Newfoundland, bbl.	gal.	.65 - .67	.65 - .67	.68 - .69
Menhaden, light pressed, bbl.	gal.	.65 - .70	.68 - .70	.60 - .62
Crude, tanks (f.o.b. factory)	gal.	.47½-	.46 -.....	.41 -.....
Whale, crude, tanks	gal.	.80 -.....	.80 -.....	.....
Grease, yellow, loose	lb.	.06½-.....	.06¾-.....	.07½-.....
Oleo stearine	lb.	.09¾-.....	.09½-.....	.09¾-.....
Red oil, distilled, d.p. bbl.	lb.	.09¾- .10	.09½- .10	.09½- .09¾
Tallow, extra, loose	lb.	.07½-.....	.07½-.....	.08½-.....

Coal-Tar Products

		Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl.	lb.	$0.60 -$0.65	$0.60 -$0.65	$0.60 -$0.62
Refined, bbl.	lb.	.80 - .85	.80 - .85	.85 - .90
Alpha-naphthylamine, bbl.	lb.	.32 - .34	.32 - .34	.35 - .36
Aniline oil, drums, extra	lb.	.14½- .15	.14½- .15	.15 - .16
Aniline salts, bbl.	lb.	.24 - .25	.24 - .25	.24 - .25
Anthracene, 80%, drums	lb.	.60 - .65	.60 - .65	.60 - .65

Coal Tar Products (Continued)

		Current Price	Last Month	Last Year
Benzaldehyde, U.S.P., dr.	lb.	1.15 - 1.25	1.15 - 1.35	1.15 - 1.25
Benzidine base, bbl.	lb.	.65 - .67	.67 - .70	.70 - .72
Benzoic acid, U.S.P., kgs.	lb.	.51 - .60	.57 - .60	.58 - .60
Benzyl chloride, tech, dr.	lb.	.25 - .26	.25 - .26	.25 - .26
Benzol, 90%, tanks, works	gal.	.23 - .25	.23 - .25	.22 - .23
Beta-naphthol, tech., drums	lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr.	lb.	.14 - .17	.14 - .17	.18 - .20
Cresylic acid, 97%, dr., wks.	gal.	.68 - .70	.70 - .72	.73 - .75
Diethylaniline, dr.	lb.	.55 - .58	.55 - .58	.58 - .60
Dinitrophenol, bbl.	lb.	.30 - .32	.30 - .31	.31 - .35
Dinitrotoluen, bbl.	lb.	.17 - .18	.17 - .18	.17 - .18
Dip oil, 25% dr.	gal.	.26 - .28	.26 - .28	.28 - .30
Diphenylamine, bbl.	lb.	.42 - .43	.42 - .43	.45 - .47
H-acid, bbl.	lb.	.60 - .63	.60 - .63	.63 - .65
Naphthalene, flake, bbl.	lb.	.04½ - .05	.04½ - .05	.05 - .06
Nitrobenzene, dr.	lb.	.09 - .10	.09 - .10	.08½ - .10
Para-nitraniline, bbl	lb.	.55 - .56	.55 - .56	.52 - .53
Para-nitrotoluine, bbl.	lb.	.29 - .31	.29 - .31	.28 - .32
Phenol, U.S.P., drums	lb.	.13½ - .15	.13½ - .15	.15 - .17
Picric acid, bbl.	lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr.	lb.	1.75 - 1.90	1.75 - 1.90	1.35 - 1.50
R-salt, bbl.	lb.	.44 - .45	.44 - .45	.47 - .50
Resorcinal, tech, kegs.	lb.	1.30 - 1.35	1.30 - 1.35	1.30 - 1.40
Salicylic acid, tech., bbl	lb.	.30 - .32	.30 - .32	.30 - .32
Solvent naphtha, w.w.,tanks	gal.	.30 - .35	.30 -	.35 -
Tolidine, bbl.	lb.	.86 - .90	.86 - .90	.95 - .96
Toluene, tanks, works	gal.	.45 -	.45 -	.35 -
Xylene, com., tanks	gal.	.30 .40	30 - .35	36 - .40

Miscellaneous

		Current Price	Last Month	Last Year
Barytes, grd., white, bbl.	ton	$23.00-$25.00	$23.00-$25.00	$23.00-$25.00
Casein, tech., bbl.	lb.	.15½ .16	.15½- .16	.15½- .16
China clay, dom.,f.o.b. mine	ton	10.00 -20.00	10.00 -20.00	10.00 -20.00
Dry colors:				
Carbon gas, black (wks.)	lb.	.08 - .13	.08 - .13	.06½- .07
Prussian blue, bbl.	lb.	.35 - .36	.32 - .33	.31 - .32
Ultramine blue, bbl.	lb.	.06 - .32	.08 - .35	.08 - .35
Chrome green, bbl.	lb.	.30 - .32	.30 - .32	.27 - .30
Carmine red, tins	lb.	6.00 - 6.50	6.00 - 6.50	5.25 - 5.50
Para toner	lb.	.70 - .75	.70 - .75	.70 - .80
Vermilion, English, bbl.	lb.	1.85 - 2.00	1.90 - 2.00	1.80 - 1.85
Chrome yellow, C. P., bbl.	lb.	.17 - .17½	.16 - .16½	.15½- .16
Feldspar, No. 1 (f.o.b. N. C.)	ton	6.50 - 7.50	5.75 - 7.00	5.75 - 7.00
Graphite, Ceylon, lump, bbl.	lb.	.07½- .08½	.08 - .08½	.08 - .09
Gum copal, Congo, bags	lb.	.07½- .08	.07½- .08	.07½- .08
Manila, bags	lb.	.16 - .17	.16 - .17	.15 - .18
Damar, Batavia, cases	lb.	.24 - .25	.24 - .25	.22 - .23
Kauri, No. 1 cases	lb.	.48 - .53	.48 - .53	.48 - .53
Kieselguhr (f.o.b. N. Y.)	ton	50.00 -55.00	50.00 -55.00	50.00 -55.00
Magnesite, calc.	ton	40.00 -	40.00 -	40.00 -
Pumice stone, lump, bbl.	lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks	lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H	bbl.	9.15 -	8.30 -	9.35 -
Turpentine	gal.	.57½-	.51 -	.51½-
Shellac, orange, fine, bags	lb.	.61 -	.61 -	.61 - .52
Bleached, bonedry, bags	lb.	.58 - .59	.56 - .58	.60 - .66
T. N. bags	lb.	.43 - .44	.42 - .43	.47 - .48
Soapstone (f.o.b. Vt.), bags	ton	10.00 -12.00	10.00 -12.00	10.00 -12.00
Talc, 200 mesh (f.o.b. Vt.)	ton	9.50 -	9.50 -	10.50 -
300 mesh (f.o.b. Ga.)	ton	7.50 -10.00	7.50 -10.00	7.50 -11.00
225 mesh (f.o.b. N. Y.)	ton	13.75 -	13.75 -	13.75 -

		Current Price	Last Month	Last Year
Wax, Bayberry, bbl.	lb.	$0.28½ $0 30	$0 28½ $0.31	$0.30 $0 32
Beeswax, ref., light	lb.	.38 - .39	36 - .39	41 42
Candelilla, bags	lb.	.21 - .22	21 - .22	.23 .24
Carnauba, No. 1, bags	lb.	.37 - .38	37 - .38	50 - .51
Paraffine, crude 105-110 m.p.	lb	04½ 05	04½- 05	04½ .05

Ferro-Alloys

		Current Price	Last Month	Last Year
Ferrotitanium, 15-18%	ton	$200.00-	$200.00-	$200.00-
Ferromanganese, 78-82%	ton	105.00-	105.00-	105.00-
Spiegeleisen, 19-21%	ton	33.00-	33.00-	32.00
Ferrosilicon, 14-17%	ton	45.00-	45.00-	45.00-
Ferrotungsten, 75-80%	lb.	1.45	1.50-	1.35- .98
Ferro-uranium, 35-50%	lb.	4.50-	4.50-	4.50-
Ferrovanadium, 30-40%	lb.	3.15- 3.75	3.15- 3.75	3.15- 3.75

Non-Ferrous Metals

		Current Price	Last Month	Last Year
Copper, electrolytic	lb.	$0.18 -	$0.18½ -	$0.14½-
Aluminum, 96-99%	lb.	.24 - .30	.24 - .26	.24 - .25
Antimony, Chin. and Jap.	lb.	.08½-	.08½-	.09½-
Nickel, 99%	lb.	.35 -	.35 -	.35 -
Monel metal, blocks	lb.	.28 -	.28 - .28	.28 -
Tin, 5-ton lots, Straits	lb.	.45½-	.45½-	.49 -
Lead, New York, spot	lb.	.069 -	.0675 -	.062 -
Zinc, New York, spot	lb.	.071 -	.0715 -	.066 -
Silver, commercial	oz.	.50¾-	.52¾-	.59 -
Cadmium	lb.	.85 - .95	.85 - .95	60 -
Bismuth, ton lots	lb.	1.70 -	1.70 -	1.85 - 2.10
Cobalt	lb.	2.10 - 2.50	2.10 - 2.50	2.50 -
Magnesium, ingots, 99%	lb.	.85 - 1.10	.85 - 1.10	.98 -
Platinum, ref.	oz.	65.00- 66.00	65.00- 66.00	76.00-76.50
Palladium, ref.	oz.	38.00- 40.00	38.00- 40.00	46.00-49.00
Mercury, flask	75 lb.	124.50-	124.50-	122.50-
Tungsten powder	lb.	1.35- 1.50	1.35- 1.50	1.05-

Ores and Semi-finished Products

		Current Price	Last Month	Last Year
Bauxite, crushed, wks.	ton	$7.50- $8.00	$7.50- $8.50	$5.50- $8.75
Chrome ore, c.f. post	ton	22.00- 25.00	22.00- 24.00	22.00- 23.00
Coke, fdry., f.o.b. ovens	ton	2.85- 3.00	2.85- 3.00	2.85- 3.00
Fluorspar, gravel, f.o.b. Ill.	ton	18.00- 20.00	18.00- 20.00	16.00-
Ilmenite, 52% TiO_2, Va.	ton	9.50- 11.00	.00½- .00½	.00½
Manganese ore, 50% Mn., c.i.f. Atlantic Ports	unit	.31 - .36	.34 - .37	.36 - .38
Molybdenite, 85% MoS_2 per lb. MoS_2, N. Y.	lb.	.48 - .50	.48 - .50	48- .50
Monazite, 6% of ThO_2	ton	80.00-	80.00-	130.00-
Pyrites, Span. fines, c.i.f.	unit	.13 -	.13 -	.13 -
Rutile, 94-96% TiO_2	lb.	.10 - .11	.11 - .13	.11 - .13
Tungsten, scheelite, 60% WO_3 and over	unit	16.00- 17.00	15.00 -	10.50 -10.75
Vanadium ore, per lb. V_2O_5	lb.	40.00- 45.00	.28 -	nom. - n.m.
Zircon, 99%	lb	.03 -	.03 -	03 -

CURRENT INDUSTRIAL DEVELOPMENTS

New Construction and Machinery Requirements

Alloy Foundry—General Electric Co., River Rd., Schenectady, N. Y. is receiving bids for the construction of a 1 story alloy foundry. C. E. Schnur, Schenectady, N. Y., is engineer.

Battery Factory—Willard Storage Battery Co., 1601 South Hope St., Los Angeles, Calif., is having plans prepared for the construction of a battery factory at 9th St. Estimated cost $500,000. C. Beelman, 1019 Union Bank Bldg., Los Angeles, is architect.

Bronze Factory — Eagle Bronze Works, Inc., North Bleecker St., Mount Vernon, N. Y., has work under way on the construction of a 3 story plant. Estimated cost $60,000. G. M. Bartlett, 103 Park Ave., New York, is architect.

Bronze Foundry — John Harsch Bronze & Foundry Co., J. Harsch, Pres., 11612 Madison Ave., Cleveland, O., plans the construction of a 1 story bronze foundry on West 121st St. Estimated cost $75,000. Architect not selected.

Bronze and Aluminum Foundry — National Bronze & Aluminum Co., East 88th St. and Laisey Ave., Cleveland, O., plans the construction of a 1 story, 71 x 109 ft. foundry. Estimated cost including equipment $50,000.

Service Building—Anaconda American Brass Ltd., New Toronto, Ont., awarded contract for foundation for a 2 story service building in connection with $500,000 expansion program to Anglin-Norcross Ltd., Temple Bldg., Toronto. Estimated cost $75,000.

Tube Mill Addition — Aluminum Co. of America, New Kensington, Pa., will build a 1 story, 155 x 425 ft. addition to tube mill including draining and heat treating equipment, also 1 story, 140 x 840 ft. melting room at Arnold, Pa. Work will be done by separate contracts.

Bakelite Factory—Bakelite Corp., L. M. Rossi, V. Pres., 350 Rector St., Perth Amboy, N. J., awarded contract for a 2 story factory on River Rd., Piscataway to Francisco & Jacobus, 511 5th Ave., New York, N. Y., Engrs. and Contrs. Estimated cost $40,000. Architect not announced.

Carbide and Carbon Factory—Union Carbide & Carbon Corp., 30 East 42nd St., New York, awarded contract for a 2 story, 50 x 100 ft. factory at Birmingham, Ala., to A. J. Honeycutt, Martin Bldg., Birmingham. Estimated cost $55,000.

Carbon Black Plant—S. C. Henderson Gasoline Co., Amarillo, Tex., is having preliminary plans prepared for the construction of a carbon black plant in Sanford Dist. Private plans.

Carbon Black Plant—C. F. Spencer & Associates, Borger, Tex., plans the construction of second unit of carbon black plant, 10,000,000 cu.ft. residue gas daily. Estimated cost $200,000.

Ribbon and Carbon Factory—Buckeye Ribbon & Carbon Co., 1486 East 55th St., Cleveland, O., awarded contract for a 2 story factory at 1468 East 55th St. to Bolton-Pratt Construction Co., Columbia Bldg., Cleveland. Estimated cost $50,000.

Cement Plant — Port Stockton Cement Co., Claus Spreckels Bldg., San Francisco, Calif., awarded contract for the construction of a cement plant at Stockton to Macdonald Engineering Co., 140 California St., San Francisco. Estimated cost $1,400,000.

Chemical Factory—William S. Merrell Co., J. and Pike Sts., Cincinnati, O., plans the construction of a 2 story factory for the manufacture of pharmaceuticals and salicylic acid on Carthage Ave. Estimated cost $500,000. Tietig & Lee, 34 West 6th St., Cincinnati, are architects.

Chemical Factory—Paper Makers' Chemical Corp., Kalamazoo, Mich., manufacturers of industrial chemicals, plans the construction of a new branch factory at Portland, Ore. Estimated cost $275,000.

Chemical Plant—Plough Chemical Co., 121 South Second St., Memphis, Tenn., will receive bids until Sept. 21, for the construction of a plant at South Parkway and Southern R.R. Estimated cost $1,000,000.

Chemical Plant—Vestal Chemical Co., T. J. Pollnow, Pres., 215 Pine St., St. Louis, Mo., will soon award contract for a 3 story, 60 x 120 ft. chemical plant at Manchester and Kingshighway. L. Haeger, 3844 Utah St., St. Louis, is architect.

Chemical Plant Addition—Dow Chemical Co., Midland, Mich., awarded contract for a 1 and 2 story, 50 x 140 ft. addition to chemical plant for the manufacture of calcium chloride, etc. to Walbridge-Aldinger Co., 1300 Buhl Bldg., Detroit. Estimated cost $50,000.

Chemical Warehouse — Harshaw Fuller & Goodwin Co., Swanson and Jackson Sts., Philadelphia, Pa., awarded contract for a 2 story, 60 x 100 ft. warehouse in connection with chemical plant to A. Raymond Raff Co., 1635 Thompson St., Philadelphia.

Chemical Plant and Warehouse—Calco Chemical Co., G. A. Berry, V. Pres., Bound Brook, N. J., is receiving bids for a 2 and 3 story plant and warehouse. F. Joannes, 420 Lexington Ave., New York, N. Y., is architect.

Drier Plant—National Pigment & Chemical Co., 1 Sidney St., St. Louis, Mo., awarded contract for a 1 story, 40 x 160 ft. at Cadet to Fruin-Colnon Contracting Co., Merchants-Laclede Bldg., St. Louis.

Cotton Compress Plant Addition—Los Angeles Compress & Warehouse Co., San Pedro, Calif., awarded contract for a 1 story, 200 x 250 ft. addition to cotton compress plant to W. P. Neil & Co., 4814 Loma Vista, Los Angeles. Estimated cost $80,000.

Cotton Compress Plant — St. Louis Cotton Compress Co., 408 Federal Commerce Bldg., St. Louis, Mo., plans the construction of a 1 story, 180 x 1,980 ft. addition to cotton compress plant at Southern Terminal R.R. tracks East St. Louis, Ill. Work will be done by separate contracts under the supervision of W. J. Knight & Co., 904 Wainwright Bldg., St. Louis.

Cotton Oil Mill—Buckeye Cotton Co., Scott Ave., Memphis, Tenn., plans the construction of a 3 story, 85 x 400 ft. mill. Estimated cost $100,000. Robert & Co., Bona Allen Bldg., Atlanta, Ga., are engineers.

Enameling Factory—General Porcelain Enameling Co., 4101 Parker Ave., Chicago, Ill., let masonry contract for a 1 story, 26 x 125 ft., enameling factory at 4120 Schubert Ave.

Dictograph Products Factory — Dictograph Products Co., 220 West 42nd St., New York, N. Y., plans the construction of a 100 x 100 ft. factory at 95th Ave. and 149th St., Long Island City. Estimated cost $50,000. B. Ahlers Construction Co., 110 West 40th St., New York, is architect.

Factory—Norton Co., 11 North Jefferson St., Chicago, Ill., manufacturers of abrasive grinding wheels, sharpening stones, etc. is having plans prepared for a 1 story, 160 x 285 ft. factory at 47th Pl. and Turner Ave. Estimated cost $110,000. Mundie & Jensen, 39 South LaSalle St., Chicago, are architects.

Fertilizer Plant — American Manganese Fertilizer Corp., c/o A. S. Duin, 1422 F St. N. W., Washington, D. C., recently organized, plans a new plant at Alexander, Va. Estimated cost including equipment $150,000.

Fibre Factory—Spaulding Fibre Co., G. E. Calhoun, Mgr., 124 St. Clair Ave., Cleveland, O., awarded contract for a 1 story, 100 x 100 ft. factory and office on Hamilton Ave. to Julius Linder, 15615 West Delaware Rd., Lakewood. Estimated cost $50,000. Former contract recinded.

Gas Plant—Consumers Utilities Co., Winchester, Va., plans the construction of an artificial gas plant with high pressure distribution system, at Harrisonburg. Estimated cost $100,000.

Factory — Franklin Oil & Gas Co., G. W. Shaw, Pres., Bedford, O., awarded contract for a 2 story, 65 x 110 ft. factory and warehouse at Bedford to The Austin Co., 16112 Euclid Ave., Cleveland, O. Estimated cost $60,000.

Fireplace Factory—Castle Shell Cast Fireplaces Ltd., E. J. Castle, Mgr., Leamington, Ont., interested prices complete equipment for the manufacture of concrete, stone, brick and composition fireplace. Estimated cost $25,000.

Gasoline Cracking Plant—Orient Petroleum Co., 352 Harvey-Snider Bldg., Wichita Falls, Tex., subsidiary of Atlantic & Pacific and Gulf Oil Co., Kansas City, Mo., is having plans prepared for the construction of a gasoline cracking plant at Wichita Falls. Estimated cost $250,000.

Glass Factory — Hazel Atlas Glass Co. of California, Ltd., First National Bank Bldg., Oakland, Calif., awarded contract for first unit of glass factory S-G St. to Larsen & Larsen, Russ Bldg., San Francisco. Estimated cost $35,000.

Glass Factory — Pittsburgh Plate Glass Co., Grant Bldg., Pittsburgh, Pa., awarded contract for a 110 x 177 ft. glass factory at Henryetta, Okla. to W. S. Bellows, 612 Oklahoma National Bldg., Oklahoma City, Okla.

Kid Plant Addition—Benz Kid Co., 215 Market St., Lynn, Mass., awarded contract for the construction of a factory at Marion and Boston Sts. to W. T. Dinneen Construction Co., 23 Central Ave. Estimated cost to exceed $75,000.

Laboratory—Union College, F. P. Day, Pres., Union Ave., Schenectady, N. Y., will soon award contract for the construction of a 3 story laboratory. Estimated cost $200,000. H. C. Severance, 36 West 44th St., New York, is architect.

Laboratory, etc.—City of Brownsville, Tex., plans a laboratory and equipment for testing water, also modern device for applying chemicals in treatment of water supply and prechlorinating device, etc., in connection with proposed waterworks. Estimated cost $75,000.

Laboratories, Etc.—City Hospital, 960 Locke St., Indianapolis, Ind., is having plans prepared for a hospital including laboratories, service, building, etc. Estimated cost $500,000. R. F. Daggett, 922 Continental Bank Bldg., Indianapolis, is architect.

Laboratory (Research)—Gulf Refining Co., Sydenham and Locust Sts., Philadelphia, Pa., awarded contract for the construction of a research laboratory at Penrose and Gallows Sts. to Cramp Co., Denckla Bldg., Philadelphia.

Laboratory Equipment, Etc.—Bd. of Education, Cincinnati, O. C. W. Handman, Bus. Mgr., Cincinnati, O., will receive bids until Sept. 23 for battery repair equipment, engine laboratory brake horsepower testing equipment, laboratory equipment, painting equipment, etc. for Automotive Trades school.

Manufacturing Building—Presto-O-Lite Co., subsidiary of Union Carbide & Carbon Co., 30 East 42nd St., New York, N. Y., awarded contract for a 1 and 2 story manufacturing building at Tampa, Fla.

Match Factory — Hull Match Co., St. Redempeur St., Hull, Que., awarded contract for the construction of a match factory to A. J. Byers & Co., 1226 University Ave., Montreal. Estimated cost $200,000.

Galvanizing Plant — International Derrick & Equipment Co., Columbus, O., acquired a 10 acre site near ship canal, Houston and has work under on a structural and galvanizing plant for the manufacture of Ideco products.

Tinalium Factory—A. Tinnally, El Paso, Tex., has purchased a site and plans the construction of a factory for the manufacture of patented preservative compound of metals known as Tinalium. Estimated cost $2,000,000.

Mirror Factory — Liberty Mirror Co., 6615 Kelly St., Pittsburgh, Pa., awarded contract for a 1 story, factory on South Railroad St. to Blaw Knox Co., Blaw Knox, Pa. Estimated cost $160,000.

Paint Shop, Etc.—McAvoy Varnishing Process Co., A. Keiser, 7714 Carnegie Ave., Cleveland, O., had plans prepared for a 1 story, 66 x 118 ft. paint shop, etc. Estimated cost $80,000. W. J. Wefel, 5716 Euclid Ave., Cleveland, is architect.

Paint and Varnish Factory — Glidden Corp., 209 14th St., Elmhurst, L. I., New York, plans the construction of a 2 story, 49 x 53 ft. paint and varnish factory at Corona Ave. and 91st Pl. Estimated cost $40,000. Francisco & Jacobus, 511 5th Ave., New York, N. Y., are architects.

Paper Mill Addition — Consolidated Water Power Paper Co., Wisconsin Rapids, Wis., awarded contract for addition to paper mill, including 1 story, 53 x 112 ft. filter plant and 2 story, 68 x 113 ft. finishing room, to T. Utegaard, Wisconsin Rapids.

Paper Factory—Marathon Paper Mills, W. M. Zahn, Purch. Agt., Rothchild, Wis., awarded contract for a 2 story paper mill at Menasha to Worden Allen Co., Pt. Washington Rd., Milwaukee, Wis. Estimated cost $150,000.

Paper Plant — National Blank Book Co., Riverside, Holyoke, Mass., awarded contract for a 5 story, 60 x 150 ft. factory to Casper Ranger Construction Co., 20 Bond St., Holyoke. Estimated cost $160,000.

Paper Products Factory — Western Paper Products Co., C. P. Castle, Salt Lake City, Utah, is having plans prepared for the construction of a plant and office. Estimated cost $66,000. W. C. A. Vissing, Salt Lake City, is architect.

Pulp and Paper Mill—Willapa Pulp & Paper Mills, Inc., Pacific Bldg., Portland, Ore., plans the construction of a new mill at South Bend, Wash. Estimated cost including equipment, $1,000,000.

Pottery Plant—Hall China Co., East Liverpool, O., will receive bids until March 1, for the construction of a pottery plant. Estimated cost $500,000. Architect and engineer not announced.

Radio Factory—Temple Corp., 1925 South Western Ave., Chicago, Ill., awarded contract for the construction of a 1 and 2 story factory for the manufacture of radio receiving sets and speakers at La Vergne Ave. and West 65th St. to Foltz & Co., 510 North Dearborn St., Chicago. Estimated cost $500,000.

Rayon Plant—American Chatillon Corp., 393 7th Ave., New York, N. Y., is having plans prepared for the construction of an additional unit to rayon plant at Rome, Ga. Lockwood, Greene Engineering Co., 1 Pershing Sq., New York, N. Y., are engineers.

Filter House—Continental Refining Co., P. A. Anderton, Secy., Oil City, Pa., plans to rebuild filter house on Rouseville Rd. recently destroyed by fire, 1 story, 22 x 126 ft. E. E. Bailey, 601 Chambers Bldg., Oil City, Pa., is architect.

Refinery — Metropolitan Refining Co., 570 7th Ave., New York, N. Y., plans the construction of a 1 story, 60 x 180 ft. refinery at 3rd and Oliver Sts., Long Island City. Estimated cost $75,000. Private plans.

Refinery and Smelting Plant — American Smelting & Refining Co., J. A. Betterton, Pres., Omaha, Neb., awarded contract for a 2 story, 40 x 115 ft. storage and distribution plant to Bush Construction Co., Sunderland Bldg., Omaha. Estimated cost including equipment $50,000.

Refinery (Copper) — Ontario Refining Co., Copper Cliff, Ont., has work under way on the construction of a copper refinery including 300 x 400 ft. electrolytic cell house and two 200 x 400 ft. castings buildings, one for crude copper and the other for refined copper including three furnaces. Estimated cost $5,000,000. Fraser Race & Co., 83 Craig St. W., Montreal, Que., are general contractors.

Refinery (Metal)—Pease & Curran, 104 Point St., Providence, R. I., awarded contract for a 1 story, 55 x 100 ft. addition to refinery to C. B. Maguire Co., 517 Grosvenor St., Providence. Estimated cost $35,000.

Refinery (Oil)—Allegheny-Arrow Oil Co., 210 Walnut Ave. N. E., Canton, O., awarded contract for the construction of an oil refinery, also other factory units for the manufacture of by-products to A. G. McKee Co., 2422 Euclid Ave., Cleveland. Estimated cost $100,000.

Refinery (Oil)—Henry H. Cross Co., 122 South Michigan Ave., Chicago, Ill., plans the construction of an oil refinery including storage tanks, etc., at Dupo, Ill. Estimated cost $125,000.

Refinery (Oil)—Shell Oil Co. of Canada, 276 St. James St., Montreal, Que., is having plans prepared for the construction of an oil refinery at Collingwood, Ont. Initial cost $500,000.

Refinery (Oil)—Standard Oil Co. of New York, 26 Broadway, New York, N. Y., is having sketches made for an oil refinery, oil storage tanks, etc. at Kreischerville, (Staten Island). Estimated cost $1,000,000. Private plans.

Refinery (Sugar) — Holly Sugar Corp., 453 South Spring St., Los Angeles, Calif., plans the construction of a sugar refinery at Stockton. Estimated cost $2,000,000.

Refinery (Sugar)—Western Sugar Refinery Co., 2 Pine St., San Francisco, Calif., awarded contract for a 1 and 2 story factory on 23rd St. to Barrett & Hilp, 918 Harrison St., San Francisco. Estimated cost $250,000.

Rubber Factory—Dominion Rubber Co. Ltd., 429 Laganclutier St., Montreal, Que., is having plans prepared for the construction of a factory at St. Jerome, Que. Estimated cost $400,000.

Rubber Factory—Eastern Rubber Co., Ltd., Acton Vale, Que., is having plans prepared for addition to rubber plant. Estimated cost $100,000.

Rubber Factory — Firestone Tire & Rubber Co., South Main St., Akron, O., awarded contract for a 7 story factory at Firestone Park to McArthur Concrete Pile Co. Estimated cost $50,000.

Rubber Factory — U. S. Rubber Co., 1790 Broadway, New York, N. Y., is having plans prepared for a 4 story factory at Passaic, N. J., also awarded contract for a 1 story, 100 x 105 ft. factory at Providence, R. I., to Cruise Construction Co., 19 Dexter St., Pawtucket. Estimated cost $1,000,000 and $100,000 respectively.

Tile Factory — National Tile Co., Anderson, Ind., awarded contract for a 1 story, 108 x 414 ft. factory including modern dry kilns for tile drying, at 26th and Lynn Sts. Estimated cost $70,000. E. F. Miller, Anderson, is architect. Machinery for the manufacture of colored wall and floor tile will be required.

Tile and Mosaic Factory—Zani Tile & Mosaic Co., 43 Auburn St., Chelsea, Mass., is having revised plans prepared for a 1 story factory. Estimated cost $45,000. Private plans. Former bids rejected.

Tobacco Processing Plant—Imperial Tobacco Co., 3810 St. Antoine St., Montreal, Que., plans the construction of a tobacco processing plant and power plant at Delhi, Ont. Estimated cost $150,000. Private plans.